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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume XI - Cincinnati

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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This document is one volume of a sixteen-volume report presenting an overall assessment of the particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of fourteen single-area volumes that provide working summaries of data gathered in the fourteen urban areas studied. These city reports primarily provide documentation and background information for Volume I of the study - National Assessment of the Particulate Problem - Final Report. Volume I should be considered the primary output of the report.

Descriptors	Identifiers	
Particulate Matter Total Suspended Particulate Emission Sources Control Methods Air Quality Measurements	Optical Microscopy Secondary Particulates Fuel Combustion Process Emissions Fugitive Emissions Fugitive Dust Monitor Siting Meteorology	
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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume XI
Cincinnati, Ohio

FINAL REPORT

by

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

June 1978

This Final Report was furnished to the Environmental Protection Agency by the GCA/Technology Division in fulfillment of the requirements under Contract No. 68-02-1375, Task Order No. 18. The contents of this report are reproduced herein as received from the contractor. The opinions, findings and conclusions are those of the authors and not necessarily those of the Environmental Protection Agency.

FOREWORD

This document is part of a 16-volume report assessing the urban particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of the 14 single city volumes that provide working summaries of data gathered in the 14 urban areas during 1974 to support an assessment of the general nature and extent of the TSP problem nationwide. No attempt was made to perform detailed or extensive analyses in each urban area. Rather, the city reports are intended as a collection of pertinent data which collectively form a profile of each urban area. This, in turn, contributes to a comparative analysis of data among the 14 areas in an attempt to identify general patterns and factors relating to attainment of the TSP problem nationwide. Such an analysis has been made in Volume I of the study-National Assessment of the Urban Particulate Problem-National Assessment. The reader is referred to this volume as the summary document where the data is collectively analyzed.

This and the other 13 city reports are viewed primarily as working documents; thus, no effort was made to incorporate all the reviewers' comments into the text of the report. The comments were, however, considered during the preparation of Volume I and are included herein in order to alert the reader to different points of view. The 16 volumes comprising the overall study are as follows:

Volume	I - National Assessment of the Urban Particulate Problem
Volume	II - Particle Characterization
Volume	III - Denver
Volume	IV - Birmingham
Volume	V - Baltimore
Volume	VI - Philadelphia
Volume	VII - Chattanooga
Volume	IX - Oklahoma City
Volume	X - Seattle
Volume	XI - Cincinnati
Volume	XII - Cleveland
Volume	XIII - San Francisco
Volume	XIV - Miami
Volume	XV - St. Louis
Volume	XVI - Providence

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EXECUTIVE SUMMARY

AIR QUALITY LEVELS AND TRENDS

The 1974 geometric mean TSP concentrations in Cincinnati and Hamilton County ranged from less than 60 ug/m^3 at three monitors in suburban areas to around 75 ug/m^3 at several sites in residential areas and over 100 ug/m^3 in the industrialized Mill Creek Valley. Seven of the 25 sites in the county exceeded the national primary standard of 75 ug/m^3 and 14 other sites exceeded the secondary standard of 60 ug/m^3. The 24-hour primary standard was exceeded on two sampling days (0.1 percent) and the 24-hour secondary standard was exceeded on 61 sampling days (4.2 percent). Air quality has been improving for the past 10 years -- annual geometric mean TSP concentrations decreased 70 ug/m^3 at the NASN site in the center city. An average decrease of 19 ug/m^3 occurred from 1970 to 1974 at the seven city sites that sampled during that time.

REGIONAL SETTING

The City of Cincinnati is located in Hamilton County in the southwestern corner of the State of Ohio along the Indiana and Kentucky borders. The Ohio River forms the southern border of the county. Due to its location on the Ohio River and its proximity to the coal fields of West Virginia, Kentucky, Pennsylvania, and Ohio, Cincinnati has become an important transportation and manufacturing center. Cincinnati is located in a basin area of the Ohio River flood plain which is surrounded by steep bluffs cut by streams and rivers and rising 200 to 400 feet to the level of the upland plain.

There is a high degree and a wide variety of manufacturing activity, most of which is concentrated along the Ohio River and in the Mill Creek Valley and the Norwood Trough.

METEOROLOGY

Cincinnati has a moderate climate, averaging 5070 heating degree days per year, and moderate rainfall, an average of 39 inches per year. Nocturnal inversions occur frequently in the valleys during the summer and fall. Extended periods of poor dispersion occur during the fall.

Cincinnati frequently experiences poor dispersion conditions due to low wind speeds and frequent inversions. Since the industrial areas of the county lie in valleys where inversions tend to occur, the effects of industrial particulate emissions are magnified. A significant negative correlation ($r = -0.583$) was observed between monthly TSP concentrations and monthly mean afternoon mixing height. Slight but not statistically significant correlations between the TSP and annual rainfall trends ($r = -0.309$) and between the TSP and annual heating degree-days trends ($r = 0.255$) were observed.

Transport levels of TSP into Cincinnati have not been quantified but because of the rural character of the surrounding region are lower than in the more generally industrialized areas in the northeastern part of the country. Highest transport levels probably occur during periods of sustained southerly flow resulting either from a stagnating anticyclone over the eastern U.S. or from the westward extension of the Bermuda High.

URBAN ACTIVITY

Cincinnati has been conducting urban development and highway construction programs for the past 15 years. In general, data is not available to quantify the effects of construction activity on TSP

concentrations, except for the Public Library monitoring site where the annual geometric mean increased 25 $\mu g/m^3$ during 1964 through 1966 when a considerable amount of demolition was occurring nearby. There is a strong relationship between annual (TSP) concentrations and the predominant land use surrounding the monitoring sites. Traffic counts did not show a correlation with TSP concentrations.

REGULATIONS AND ENFORCEMENT

The air pollution control regulations for the State of Ohio and the City of Cincinnati are much the same, with some of the city's regulations being more stringent, and about average when compared with the regulations of most states in the nation. The Division of Air Pollution Control of Cincinnati is responsible for surveillance and enforcement in three areas -- the city, the nine communities comprising the Intercommunity Air Pollution Control Program, and the four counties of the Southwestern Ohio Air Pollution Control area. The deadline for compliance with the regulations is April 15, 1977 -- most industries are already in compliance but several of the larger sources are in the process of installing controls or undergoing changes. Applications for permits and variances are evaluated by the Division, then sent with recommendations to Ohio EPA for approval. Surveillance and enforcement of the regulations are rigorous. Most violations and problems are settled on the local level with only a few cases being sent to Ohio EPA for litigation or adjudication. The full impact of the emission reductions resulting from the regulations and enforcement cannot be determined yet but so far appear to be considerable.

EMISSIONS

Cincinnati is a highly industrial city. The major source of particulate emissions are power plant coal combustion and industrial fuel consumption and processes. The sampling sites nearest the industrial

areas of Cincinnati have consistently recorded the highest TSP concentrations and continue to exceed the national annual primary standards. An air quality model of Cincinnati in 1975 determined that the emission sources most affecting TSP concentrations at certain sampling sites were area sources and fuel combustion point sources. Considerable reductions in particulate emissions have occurred due to fuel switching from coal to natural gas in homes, industries, and power plants since the 1950's and, more recently, to emission controls and to different methods of solid waste disposal. Emission reductions will continue as the remaining sources come into compliance by the deadline in 1977 and TSP concentrations will probably continue to decrease. But uninventoried fugitive dust and fugitive emissions which were not taken into account by the model may prevent further TSP reductions.

NETWORK DESIGN

The design of the network is generally adequate for recording air quality in the various kinds of land development in the areas, except that there does not appear to be a background site. The specific siting -- the height, location, and exposure -- of the monitors seems to be adequate. The elevation of the monitors is influential through the effects of inversions and land use patterns -- the lower elevation sites are near the center city and industrial areas and experience the effects of inversions.

CONCLUSIONS

Annual mean TSP concentrations in the past exceeded the annual standards due to the high degree of industrial activity in Cincinnati, widespread coal combustion, and the poor dispersion characteristics of the region. The NASN site since 1966 and several sites in the center city and industrial areas since 1970 have experienced decreases in TSP concentrations because of fuel switching, vigorous enforcement of the regulations, and industrial and utility emissions controls. The sampling sites farthest from the city are meeting the standards and the suburban sites in and

near the city are experiencing concentrations just above the secondary standard, but the industrial and center city sites continue to exceed the primary standard. Full compliance with the regulations by particulate sources will be achieved soon and will probably decrease TSP concentrations further as indicated by the air quality model, but poor dispersion in the industrial valleys and fugitive emissions and dust will continue to influence TSP concentrations and may prevent attainment of the standards.

REVIEWERS' COMMENTS

The draft report for each city was submitted to interested EPA, state, and local officials for comment on the contents and findings. Comments of an editorial nature were reconciled; comments of a substantive nature which reflect differences of opinion were compiled and are presented below.

Pages 15, 38, and 56	-	The reviewer notes that there are sampling sites below the NAAQS located between the power plants and the sites exceeding the NAAQS, and that it is unlikely that the power plants are having much effect on Cincinnati's air quality.

SECTION I

INTRODUCTION

CITY CHARACTERIZATION

The City of Cincinnati is located in Hamilton County in the southwestern corner of the State of Ohio. The county is bordered by the State of Indiana to the west and by the Ohio River, which is the border shared with Kentucky, to the south. Cincinnati is the principal city in the four-county region which is the Ohio portion of the Cincinnati Interstate AQCR and the Southwestern Ohio Air Pollution Control Region -- This includes Hamilton, Butler, Warren, and Clermont Counties (see Figure 1). Due to its location on the Ohio River and its proximity to the coal fields of West Virginia, Kentucky, Pennsylvania, and Ohio, Cincinnati has become an important transportation and manufacturing center whose most important fuel has traditionally been coal. The city is adjacent to a number of smaller, independent communities which are also highly industrialized (see Figure 2).

Topography and Climatology

Cincinnati and the area around it consist of an upland plain about 900 feet above sea level which is cut by the flood plain of the Ohio River. The basin area of the Ohio River flood plain is surrounded by steep bluffs rising 200 to 400 feet to the general level of the upland plain. These bluffs are cut by small streams and rivers, including the Mill Creek which flows through the city, the Great Miami River in the western portion of the county, and the Little Miami River on the eastern edge of the city.[1]

METROPOLITAN CINCINNATI INTERSTATE AQCR

OHIO PORTION OF THE METROPOLITAN CINCINNATI INTERSTATE AQCR

Figure 1. Ohio portion of AQCR

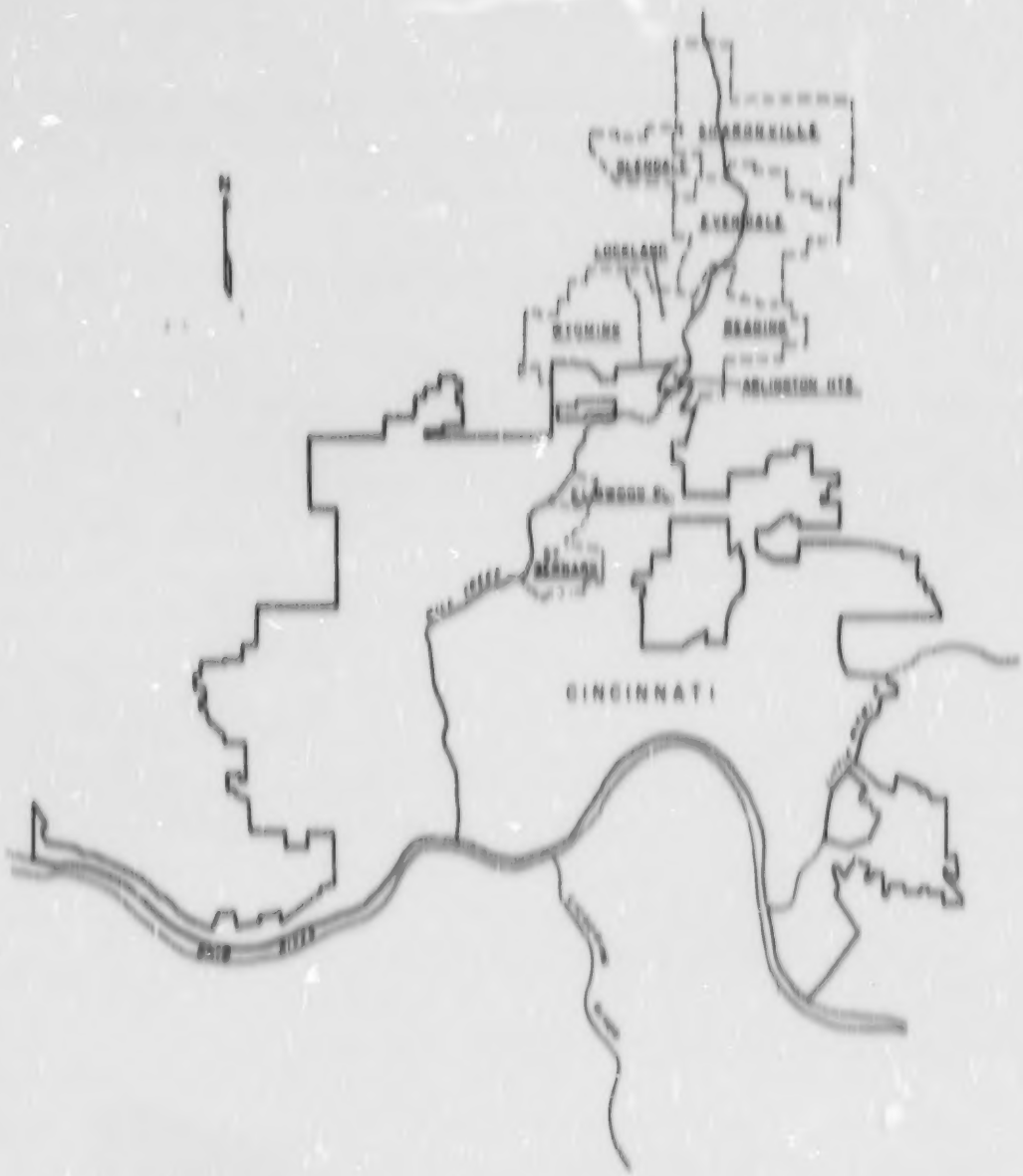

Figure 3. Ohio portion of the Cincinnati metropolitan area

Prevailing winds are from the south to southwest. In general, the hills and valleys have only a minimal effect on air movement throughout the region; however, within the steep-walled, meandering valleys, the air flow tends to be channeled.[1]

The climate is typically continental with a wide range in temperature from winter to summer. Summers are warm and humid, averaging 75°F in August, the hottest month. Winters are moderately cold -- the coldest month, January, averages 32°F -- and there are frequent periods of extensive cloudiness.[2] The city averages 5,070 heating degree days per year.

Frequent changes in weather are due to the passage of numerous cyclonic storms in winter and spring and thunderstorms during summer. Nearly one-third of the annual precipitation occurs during the summer when the prevailing south to southwest winds from the western side of the Bermuda High (a semipermanent high pressure system located over the North Atlantic) carry warm, moist air from the Gulf of Mexico up the Mississippi and Ohio River valleys. The annual average precipitation is 39.0 inches, with the fall season having the least amount.[3]

Inversions occur frequently in the valleys. Nocturnal inversions occur on more than 90 percent of the summer and fall nights in the lower Mill Creek valley. Autumn is the season when nocturnal and subsidence inversions occur most frequently -- 37 percent of the time. The lowest mean mixing heights occur in the autumn and winter months.[3,4]

Land Use, Employment, and Population Patterns

Cincinnati is the second largest city in the State of Ohio, with a population of 500,000. The population figures for the four counties in SWOAPC are shown in Table 1. The central business district is on the river and is surrounded by residential areas that decrease in density

as one moves farther out in Hamilton County. Opposite Cincinnati on the Kentucky side of the river are the smaller cities of Newport and Covington. Warren and Clermont counties in Ohio are rural in character. Butler County, Ohio, is mostly rural but has two large, industrialized towns.

Table 1. 1970 POPULATION[3]

County	Population	Population density
Hamilton	1,040,200	2,384
Butler	268,300	320
Clermont	129,600	242
Warren	113,900	284
Total	1,550,000	822

The Cincinnati area is industrial, as shown by the breakdown of employment in Table 2. The major products manufactured there are automobile parts, aircraft engines, soap products, fabricated metals, paper, and chemicals.

Table 2. EMPLOYMENT (in 1,000's)

Agricultural, forestry, fisheries	1
Mining	1
Contract construction	27
Manufacturing	195
Transportation and other public utilities	30
Wholesale trade	17
Retail trade	97
Finance, insurance, and real estate	31
Services	94
Total	517

Most of the industries are located in the Mill Creek Valley which runs from the northern part of Hamilton County through a number of independent communities to the Ohio River. Several industries are located in the northern or eastern sections of the city.

AIR QUALITY LEVELS AND TRENDS

The Division of Air Pollution Control in the City of Cincinnati samples for suspended particulates at 25 sites in Hamilton County. The locations of the sampling sites are shown in Figure 3 with the identifying site numbers. Most of the sites are located in or near the City of Cincinnati. The height above ground of the monitors ranges from near ground level (12 feet) to several stories high (80 feet), with most in the 12- to 30-foot range. The elevation above sea level varies considerably more -- from 900 feet, the elevation of the city itself near the river, to 1300 feet on top of the bluffs. Eight of the sites are in center city locations and the remainder are suburban. The center city area of Cincinnati is surrounded by bluffs, thus forming a basin where air quality tends to be uniform.

The 1974 annual geometric TSP means are shown at their respective sampling sites in Figure 4. The annual primary standard of 75 $\mu g/m^3$ is exceeded at seven sites in the county, and the annual secondary standard of 60 $\mu g/m^3$ is exceeded by 14 other sites, making a total of 21 of the 25 Hamilton County sites which exceed the annual standards. These sites are, for the most part, located in the center city, industrial, or residential areas of the county. Two sites recorded annual geometric TSP mean concentrations greater than 100 $\mu g/m^3$ -- both are located in the heavily industrialized Mill Creek valley. The national 24-hour secondary standard was exceeded on 61 of the 1460 sampling days (4.2 percent) and the 24-hour primary standard was exceeded on 2 days (0.1 percent) (see Table 3).

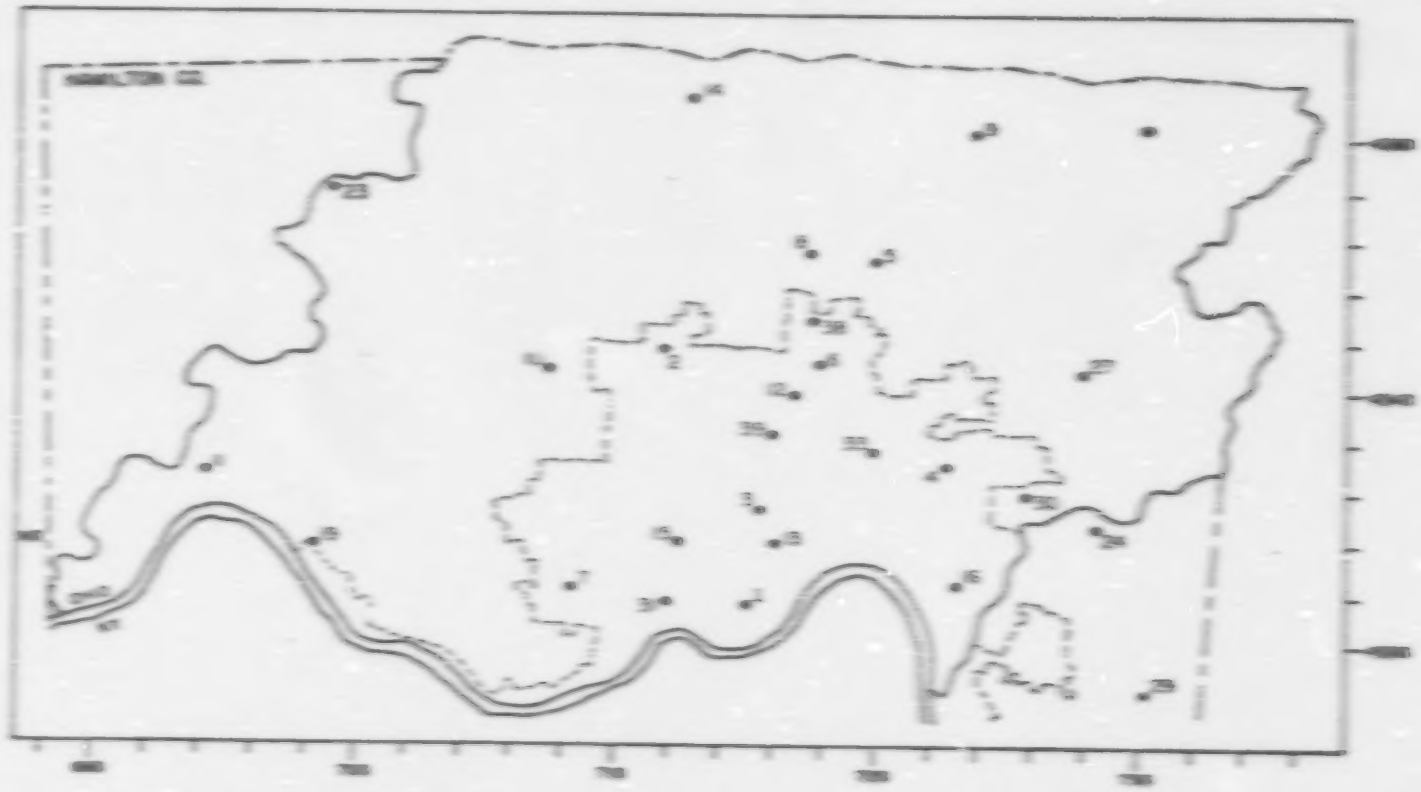

Figure 1. Locations of sampling sites in Hamilton County

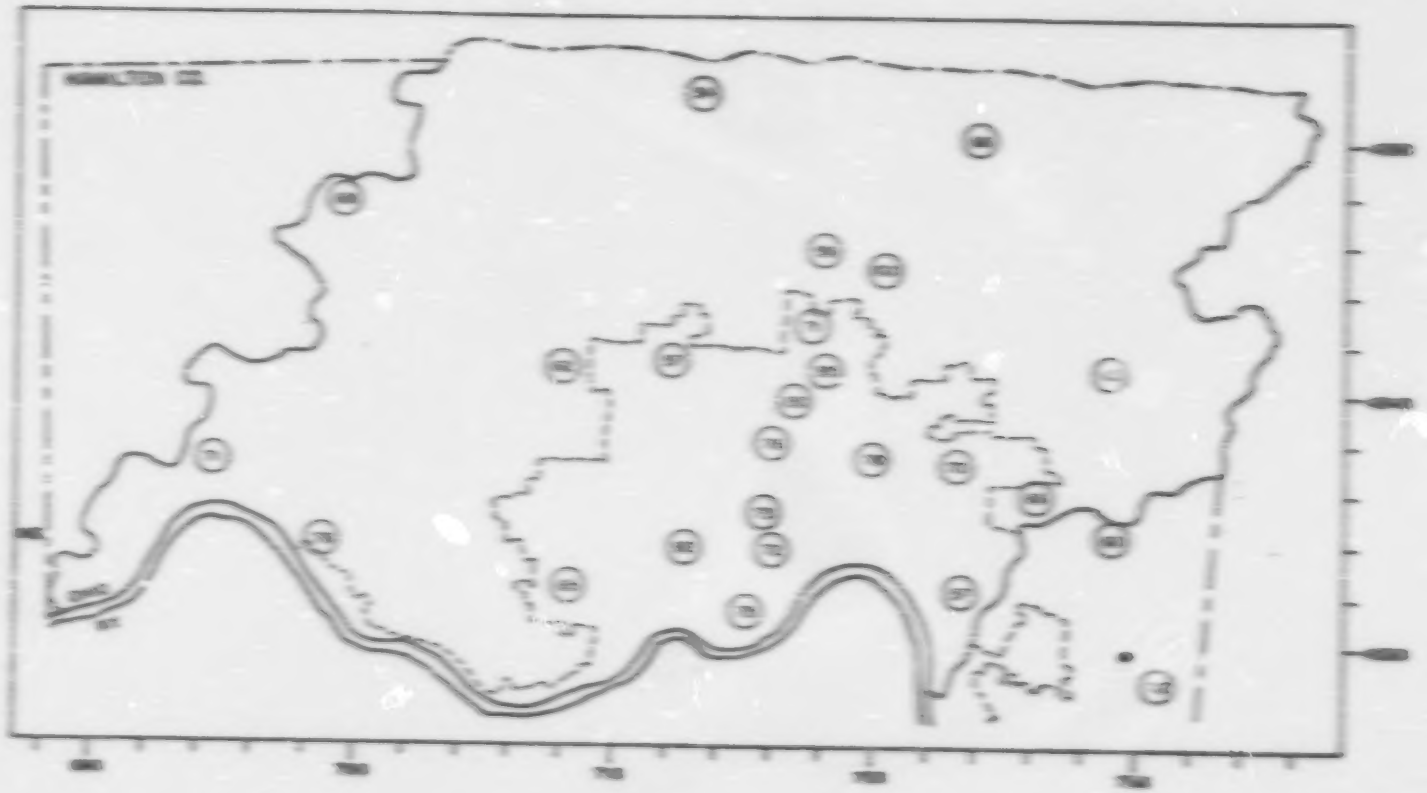

Figure 4. 1974 geometric mean TSP concentrations in Hamilton County

Table 3. SAMPLING SITES AND THE NATIONAL STANDARDS

Land use	Site number	Location	1974 TSP mean	Comparison of 1974 means with annual standards	Number of days exceeding 24-hr primary standard, 260 ug/m^3	Number of days exceeding 24-hr primary standard, 150 ug/m^3
Center city	1	Public Library	75[a]	Primary[a]	0	0
Industrial	5	Lockland	100[a]	Primary	1	14
	6	Carthage	95[a]	Primary	0	9
	12	St. Bernard	130[a]	Primary	1	21
	15	Fairmount	92[a]	Primary	0	1
	19	Addyston	76[a]	Primary	0	1
Residential	2	College Hill	57		0	0
	3	Avondale	71[b]	Secondary[b]	0	1
	7	Price Hill	65[b]	Secondary	0	2
	8	Wyoming	56		0	0
	11	Harrysville	72[b]	Secondary	0	0
	16	East End	57		0	0
	17	Norwood	78[a]	Primary	0	1
	18	Drake Hospital	71[b]	Secondary	0	0
	20	St. Bernard	76[a]	Primary	0	1
Commercial	4	Oakley	70[b]	Secondary	0	0
	27	Madeira	66[b]	Secondary	0	0

[a]Exceeds national annual primary standard of 75 ug/m^3.
[b]Exceeds national annual secondary standard of 60 ug/m^3.

Only one site has been operated for an extended period of time -- the NASN site at the Public Library. A second site, College Hill, was added in 1967, then five more in 1970. Figure 5 shows the air quality trends for these sites. Annual TSP concentrations at the Public Library fluctuated between 100 ug/m^3 and 145 ug/m^3 from 1958 to 1966, then started declining to the present level of 76 ug/m^3. The College Hill site began its decline in 1969 from 90 ug/m^3 to 57 ug/m^3 in 1974. The five sites started in 1970 showed similar decreases through 1974. From 1970 to 1974, annual TSP means at the seven sites decreased an average of 19 ug/m^3. Most of the decrease occurred from 1970 to 1971. The seven sites are located in areas in Cincinnati representing center city, residential, commercial, and industrial development.

A smoothed curve plotted for the Public Library raw TSP data for 1960 through 1974 is given in Figure 6. The smoothed curve which enables

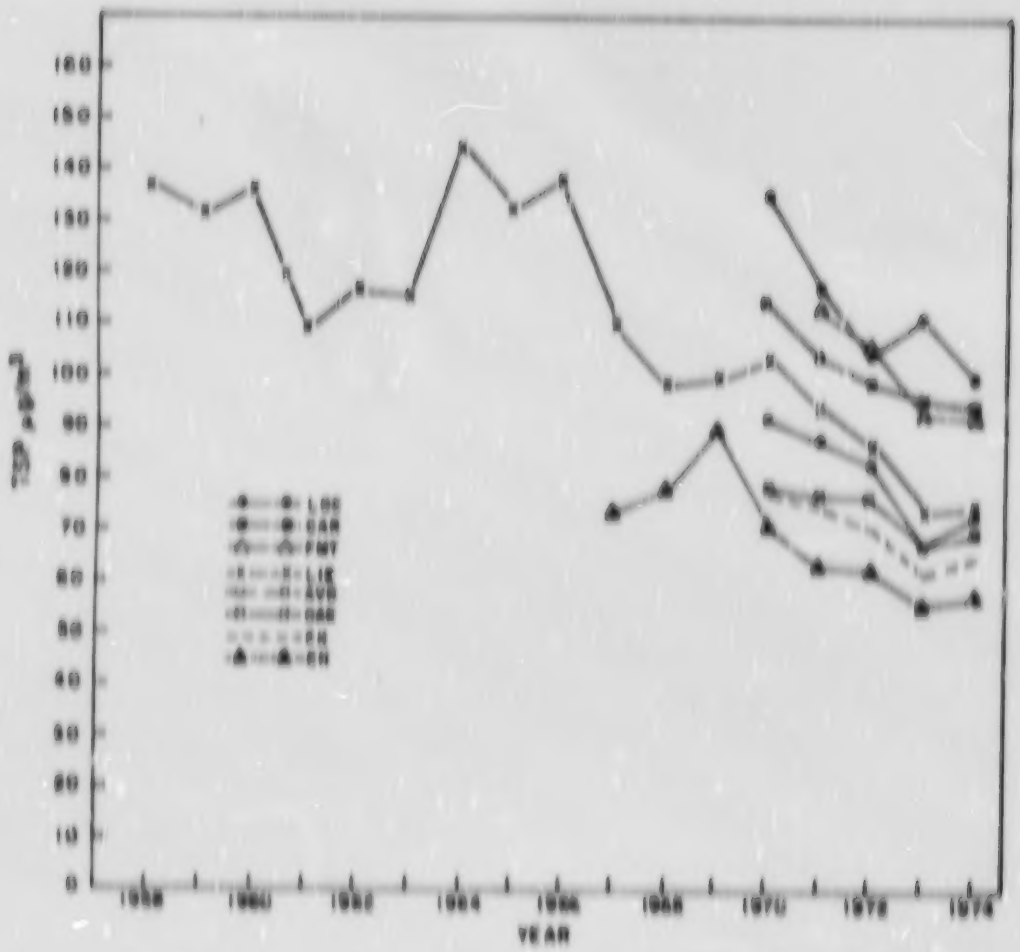

Figure 5. Trends in annual geometric mean TSP concentrations

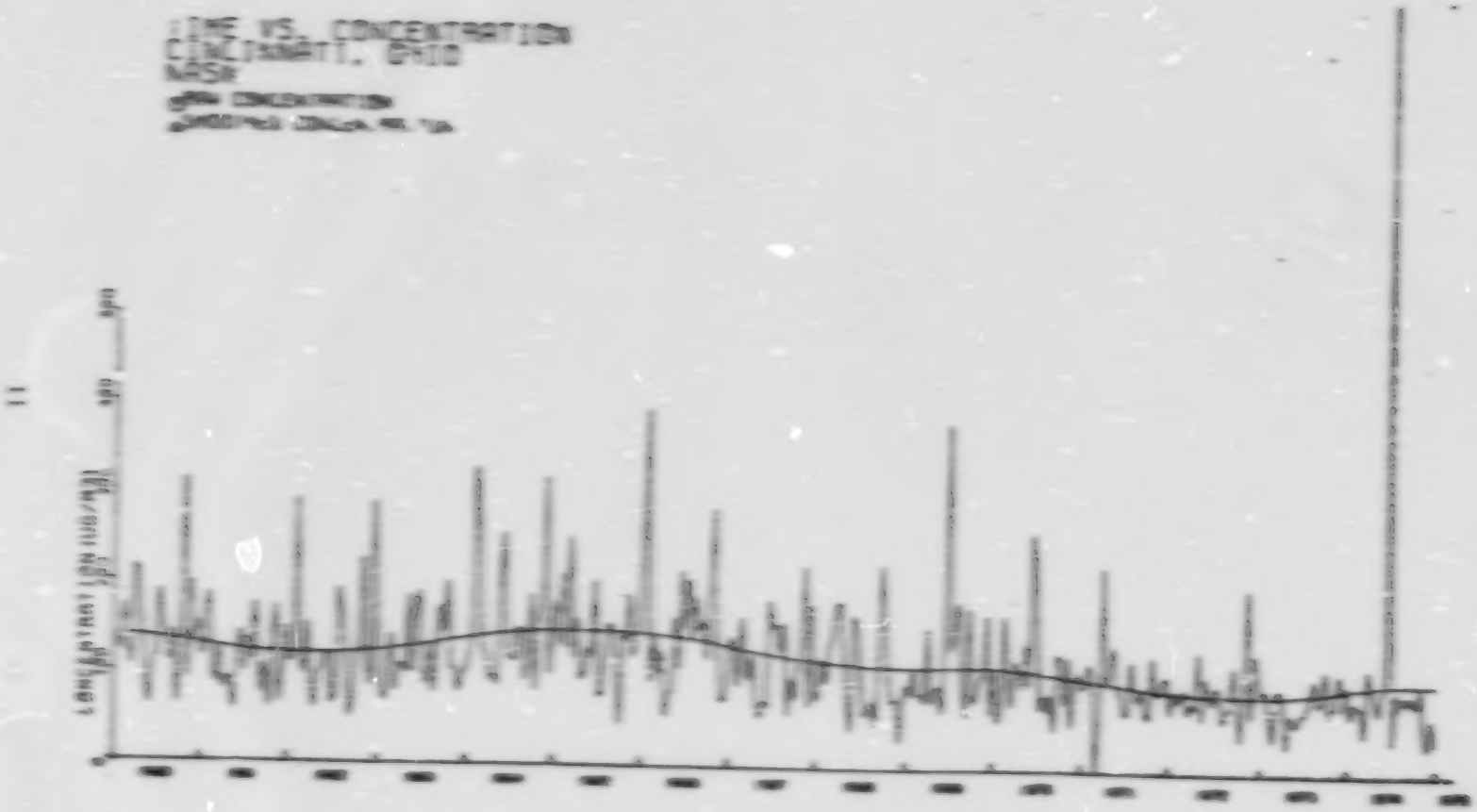

Figure 6. TSP trend at NASH site (Public Library) – raw data and smoothed trend

trends to be seen show that the Public Library experienced an upward trend of about 30 $\mu g/m^3$ until 1965 and a downward trend of about 50 $\mu g/m^3$ since then to about 100 $\mu g/m^3$ in 1974.

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1. Air Pollutant Emissions in Greater Cincinnati, 1972. Division of Air Pollution Control, Department of Sewers, City of Cincinnati.

2. Local Climatological Data- Cincinnati, Ohio, Abbe Observatory. Narrative Climatological Summary.

3. Proposed Implementation Plan for the control of particulates and sulfur oxides for the state of Ohio portion of the MCIAQCR. Resources Research, Inc. September, 1970.

4. CAMP in Cincinnati, 1961-1963. Air Quality Section, Robert A. Taft Sanitary Engineering Center.

SECTION II

ANALYSES

In this section, the factors which might be expected to affect TSP levels in Cincinnati, Ohio are considered. Analyses included are: sources and emissions, regulations and enforcement, meteorology, urban activities, and network design and monitor siting.

EMISSIONS

Emissions Inventories

Cincinnati is a manufacturing city as shown in "City Characterization," in Section I. Its location on the Ohio River, a major waterway connecting it with the coal fields of Kentucky, Ohio, West Virginia, and Pennsylvania, has meant that coal has traditionally been an important source of power, both municipal and industrial.

The 1974 particulate emissions inventory for Cincinnati and Hamilton County is presented in Table 4. It is apparent that combustion of coal by utilities is by far the most important source of particulates overall, about 75 percent of the total county emissions, and that this occurs outside the city. Industry is the next most important source - its coal combustion and process emissions account for 15 percent of the total particulate emissions. The exhaust emissions and tire wear of gasoline automobiles and trucks are third in importance at 4 percent.

Table 4. 1974 PARTICULATE EMISSIONS (TPY)

	Cincinnati	Hamilton County, excluding Cincinnati	Hamilton County
Transportation	1,646	1,846	3,492
Gas autos and trucks	1,424	1,425	2,849
Diesel buses, trucks and locomotives	218	421	639
Aircraft	4	0	4
Combustion	2,544	51,500	54,044
Coal - power plant	0	45,235	45,235
Coal - industrial and other	1,999	5,582	7,581
Natural gas	444	338	782
Oil	101	345	446
Industrial process (from chemical and mineral industries)	1,087	320	1,407
Solid Waste	501	232	733
Municipal incinerators	453	181	634
Domestic, Commercial and Institutional incinerators	48	51	99
Total	5,778	53,898	59,676

Tables 5 and 6 give information on fuel consumption and TSP emissions in 1972 in Cincinnati and Hamilton County. With respect to fuel consumption, natural gas provides slightly more than half of the total Btu produced and coal provides more than one-third. In the city, natural gas is the predominant fuel and outside the city, coal is more important due to power plant coal consumption. With respect to particulate emissions in 1972, however, coal combustion is responsible for 98 percent of the fuel combustion emissions, most of which occurs outside the city.

Two major particulate sources in the Cincinnati area - the Beckjord and Zimmer Creek power plants - are located outside Hamilton County but are considered likely to be contributing to TSP air quality in the county.

Table 5. FUEL CONSUMPTION IN 1972 - PERCENT OF TOTAL (CITY AND COUNTY) Btu OUTPUT

	Coal	Natural gas	Oil	Total
City	5.8	35.0	1.9	42.7
County, excluding city	30.0	21.5	5.8	57.3
County, including city	35.8	56.5[a]	7.7	100.0 (139.78×10^{12} Btu)

[a]The total natural gas consumption in 1972 in the county is equivalent to 2.82 million tons of coal which, if consumed, would have resulted in an additional 29,300 TPY of TSP emissions.

Table 6. TSP EMISSIONS FROM FUEL COMBUSTION 1972 - PERCENT OF TOTAL (CITY AND COUNTY) FUEL COMBUSTION TSP EMISSIONS

	Coal	Natural gas	Oil	Total
City	3.2	0.8	0.3	4.3
County, excluding city	94.8	0.5	0.4	95.7
County, including city	98.0	1.3	0.7	100.0 (56,996 TPY)

Table 7 compares the 1972 coal consumption and particulate emissions of these power plants with the major sources in Hamilton County. The two power plants alone contributed one and a half times the particulate emissions of the major sources in Hamilton County.

Table 7. TSP EMISSIONS FROM COAL COMBUSTION IN 1972

	TSP emissions	Coal consumption
Hamilton County		
Miami Fort PP outside city	47,744 TPY	934,623 T
18 industrial sources outside city	3,300 TPY	587,000 T
Industrial sources in city	1,812 TPY	290,000 T
Total	55,856 TPY	1,811,623 T
Outside Hamilton County		
Beckjord PP, Clermont County, Ohio	30,500 TPY	
Tanner Creek PP, Lawrenceburg, Indiana	49,000 TPY	
Total	81,500 TPY	3,306,191 T

The emissions inventory indicates that industry and power plants are the largest sources of particulate emissions and thus, the most influential with respect to TSP air quality. Two other analyses verify this. The sampling sites nearest the industrial areas, which are primarily in the Mill Creek Valley and the Norwood Trough, have consistently recorded high TSP concentrations over the past several years. The locations and 1972 emissions of the major industries are shown in Figure 7 with the locations of the sampling sites, and the emissions density isopleths are shown in Figure 8. Sites 5, 6, 12 and 15 are located in the Mill Creek Valley industrial corridor - their 1974 geometric mean TSP concentrations are indicated in Table 3 and Figure 4. A comparison of citywide TSP concentrations by the day of week on which they were recorded shows that TSP concentrations are considerably less on weekends than on week days - an average of 68 $\mu g/m^3$ on weekends versus 79 $\mu g/m^3$, the average on weekdays (see Figure 9). The weekend-weekday difference is probably caused by industrial operation patterns and traffic volume patterns but it is not possible to determine their separate contributions and their relative importance.

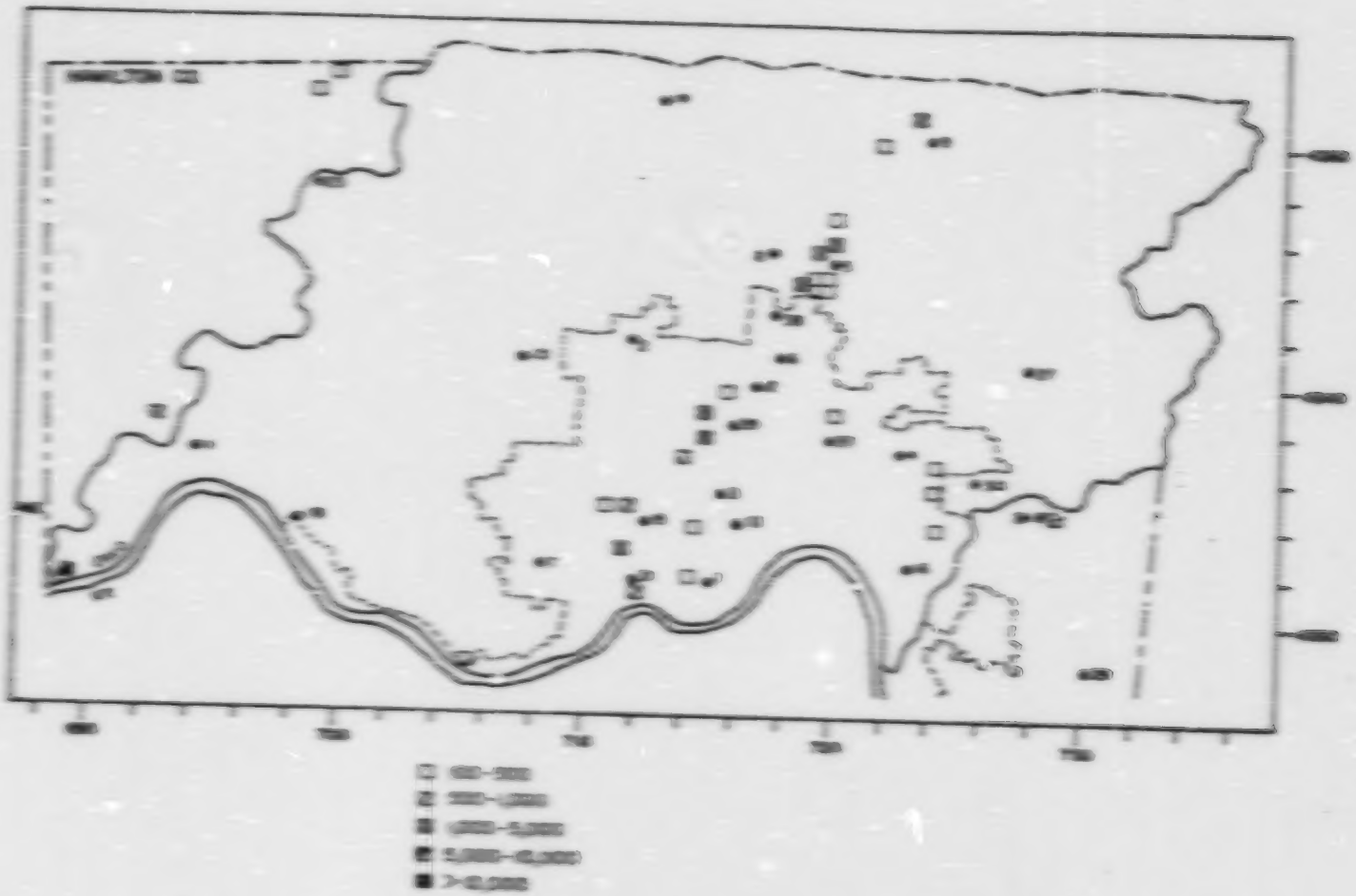
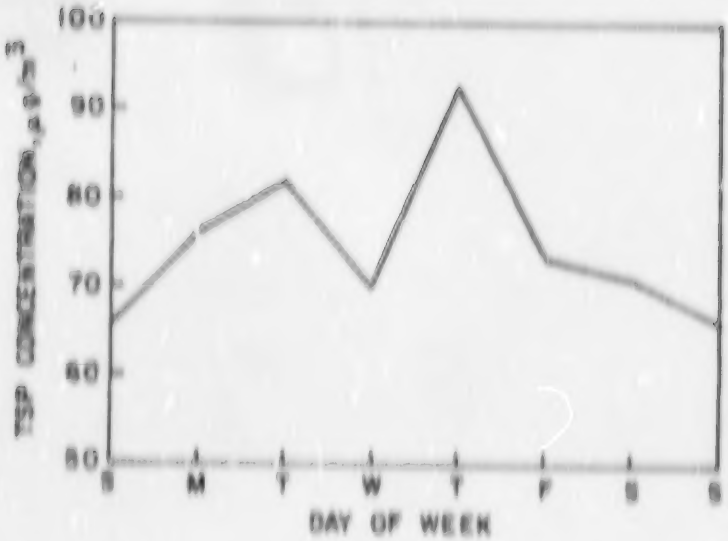


Figure 7. Locations and emissions of point sources in Hamilton County, 1972

Figure 6. Particulates emission density, 1972



Weekend average 68 $\mu g/m^3$

Weekday average 79 $\mu g/m^3$

Figure 9. 1974 Citywide average TSP concentrations by day of week

Air Quality Modeling Study

Cincinnati air quality was modeled in a study performed by the U.S. Environmental Protection Agency to assess the attainment of the TSP standards.[1] The model calculated for 1972 and 1975 the TSP concentrations at various sampling sites and the contribution of the source categories provided by emission inventories to these concentrations. The 1975 emissions inventory was based on the 1972 inventory and took into account the impact of emission control regulations. Since fugitive emissions and fugitive dust emissions were not provided in the inventories, the model calibration and results are based on the assumption that such emissions are at a constant level throughout the area and thus, part of the background. The intercept of 1972 actual and modeled TSP concentrations was used as the background level in the study -- the intercept was 58 $\mu g/m^3$. This is unusually high and is due in part to the high ambient levels measured in 1972 -- the lowest annual mean concentration was 48 $\mu g/m^3$ and most sites were in excess of 60 $\mu g/m^3$.

The modeling results and analyses of them are presented in Table 8. These indicate that the sources most responsible for TSP concentrations above the intercept of 58 $\mu g/m^3$ are point source fuel combustion and area sources. Point source fuel combustion and area sources each contribute about 40 percent of the source contribution above the intercept at most of the sites. The predictions of 1975 TSP concentrations at the ten sites indicate that the national annual primary standard is expected to be exceeded at six of the sites. These predictions were based on a projected 1975 emissions inventory which included 50 point sources in the AQCR not in compliance with the regulations. The model predicted that, once these sources come into compliance, thereby reducing their emissions, air quality would improve and values would range from 70 to 75 $\mu g/m^3$ in these areas.

Table 9. MODEL RESULTS AND COMPARISON WITH 1975 MEASURED VALUES

TSP reading site	1975 predicted	1975 – observed[a]	Percent contribution of major source categories[b]	1975 measured	Prediction differences[c]	Possible reasons for major prediction discrepancies
A Public Library	72	24	42% area sources 38% point source fuel + direction	72	0	
B College Hill	73	23	44% area sources 30% point source fuel reduction	50	+ 23	Point, mid-range emissions overpredicted on a height of land above the commercial valley
C Valley	72	22	40% area sources 37% point source fuel reduction	42	+ 6	
D Westland	61	24	40% point source fuel reduction 28% [illegible]	96	– 35	Fugitive emissions from nearby industries; fugitive dust from heavy traffic on commercial road
E Carthage	74	22	44% area sources fuel reduction 42% area sources	52	– 22	Fugitive dust from nearby I-71 and commercial valley
F Price Hill	73	23	42% area sources 36% point source fuel reduction	50	+ 7	
G Reading	74	18	40% [illegible] fuel reduction [illegible] area sources	92	+ 19	Point, mid-range emissions overpredicted from commercial valley
H St. Bernard	76	24	48% point source fuel reduction 37% area sources	113	– 37	Fugitive dust from heavy truck traffic on unpaved roads, unpaved lots and roads; fugitive emissions from surrounding industries
I Cornerville	77	28	42% area sources 40% point source fuel reduction	49	+ 28	Point, residential area on a height of land above the industrial valley
J Bankers Corner	81	73	42% point source fuel reduction 37% area sources	87	– 7	Fugitive dust from heavy traffic, bridge, railroad traffic; fugitive emissions from foundry and recycling industry

[a] The coverage of the 1972 actual and predicted TSP concentrations was 74 $\mu g/m^3$. This was the highest predicted value and was considered the background value for the study.

[b] This is the contribution of local sources to the TSP concentrations above the regional background.

[c] The difference between the 1975 actual and predicted TSP concentrations.

In order to determine how well the model predicts, the 1975 predicted TSP concentrations were compared with the 1975 TSP concentrations actually recorded. The comparison is shown in Figure 10. The range of the concentrations predicted by the model was small -- from 71 $\mu g/m^3$ to 84 $\mu g/m^3$ -- whereas the range of the actual concentrations was much larger -- from 55 $\mu g/m^3$ to 123 $\mu g/m^3$. Of the ten sites, three were substantially (by 10 $\mu g/m^3$ or more) underpredicted and three were substantially overpredicted. These large prediction discrepancies occurred at those sites which experienced an extreme, either high or low, in TSP concentration. The last column of Table 8 explains possible reasons for the discrepancies in prediction. The differences appear to be the result of inadequate simulation of localized conditions by the model -- the effects of fugitive emissions and fugitive dust and, in contrast, the effects of location in a quiet residential area on a height of land do not seem to have been taken fully into consideration.

As stated previously, the model predicted that air quality standards would be met if all emission sources were in compliance. But it is unlikely that this would occur since there are substantial discrepancies between actual and predicted concentrations at some sites which seem to be due to inadequate simulation of localized conditions. The EPA modeling study advised that the 1975 sampling data should be evaluated, all model input data verified, and the model recalibrated using the 1975 air quality data, before any conclusions are drawn about the need for additional control. A possible outcome of such additional studies might be that, even when full compliance occurs, efforts to control particulates from nontraditional sources could be called for in order to achieve air quality standards.

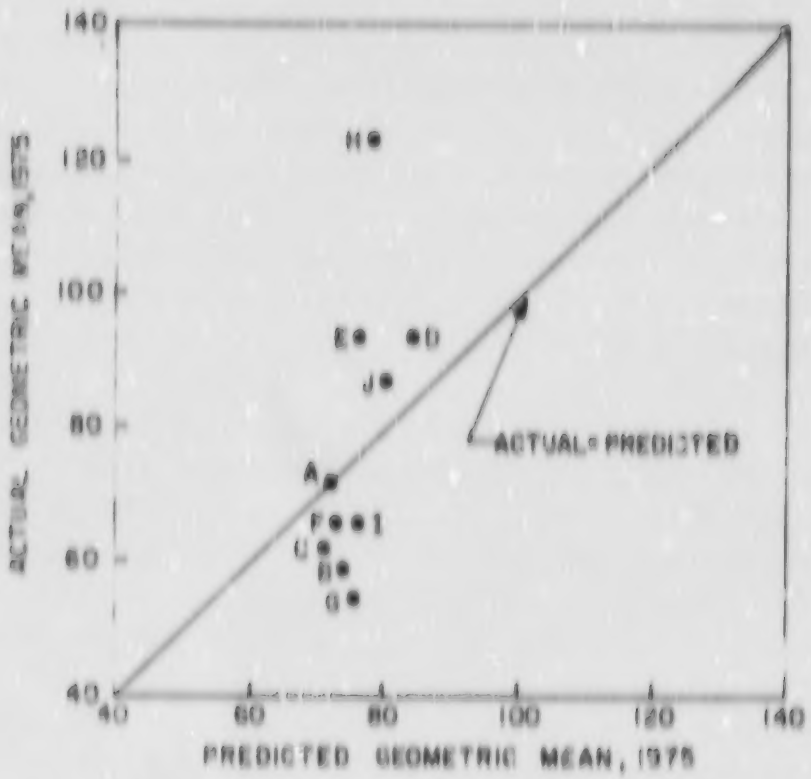


Figure 10. Comparison of actual and predicted TSP concentrations

Emissions Reductions

Considerable reductions in particulate emissions have occurred in the past and can be expected to continue until some time after the emissions compliance deadline of April 1, 1977. Table 9 shows that recent changes have occurred in emissions from industrial processes, fuel combustion, and solid waste disposal. These reductions have involved fuel switching, controls on process and combustion emissions, and changes in solid waste disposal.

Table 9. CHANGES IN EMISSIONS INVENTORIES, AQCR

	1972[a]	1975[b]	Percent change
Point sources	240,840	221,420	-8.1
Industrial process	52,630	40,920	-22.2
Industrial fuel	31,400	28,360	-9.7
Utility fuel	146,910	144,180	-1.8
Com/inst fuel	7,450	7,230	-2.9
Solid waste incineration	2,450	730	-70.2
Area sources	61,150	50,120	-20.6
Residential fuel	1,680	1,420	-15.5
Com/inst fuel	5,000	3,430	-31.4
Industrial fuel	41,980	34,890	-20.7
Solid waste	5,370	2,560	-52.3
Transportation	6,860	7,560	+10.2
Miscellaneous	260	260	0.0
	301,990	271,540	

[a]Source: NEDS.

[b]Source of point source estimates: PEDCo.
Source of area source estimates: NEDS.

Fuel switching was first started after World War II (see Tables 10 through 12). Coal combustion had been the principal source of power. Gradually, it was replaced in residences by natural gas, oil and electricity - in Hamilton County, the number of residences using coal decreased from half of the total to less than 2 percent, while the number

using natural gas increased from 43 percent to 86 percent of the total residences. Among industry in the SMSA, coal consumption decreased slightly from 1963 to 1972 (8 percent) while consumption of natural gas and oil increased 116 percent and 65 percent, respectively, during that period. The Front Street power plant in the city changed to natural gas in 1966. These long-term changes in fuel consumption have been reflected in the generally declining annual geometric TSP means recorded at the Public Library (site 1), especially since 1966 (see Figure 6). More recently, the Miami Fort Power Plant has been changing partially to oil and several industries have adopted natural gas. The natural gas and oil shortages, however, preclude any more industries or power plants changing from coal combustion. In fact there may be cases where an industry or institution which had switched from coal will be forced by the shortages to burn coal again and will be reluctant to adopt emission controls for coal combustion

Table 10. RESIDENTIAL FUEL USAGE - NUMBER OF DWELLING UNITS[a]

	Number of dwelling units			Percent change		
	1950	1960	1970	1950	1960	1970
Hamilton County						
Gas	91,855	206,752	253,010	+ 125	+ 50	+ 175
Oil	13,910	26,755	24,747	+ 92	- 14	+ 78
Coal	106,625	29,213	5,394	- 73	- 22	- 95
Electricity	100	522	9,228	+ 422	+ 8,284	+ 8,706
Cincinnati (City)						
Gas	71,445	137,277	143,891	+ 92	+ 9	+ 1,019
Oil	7,770	4,326	3,161	- 44	- 15	- 59
Coal	71,240	18,971	1,679	- 73	- 22	- 95
Electricity	80	406	6,775	+ 408	+ 7,963	+ 8,369

[a]Source: U.S. Census of Housing, 1950, 1960, 1970.

Table 11. INDUSTRIAL FUEL USAGE IN SMSA[a]

Fuel	Unit	1963	1972	Percentage difference 1963-1972
Gas	10^6 ft^3	11,504	24,900	+ 116
Oil	1,000 bbl	320	528.6	+ 65
Coal	1,000 tons	874	804.3	- 8
Coke	1,000 tons	s	s	

[a]Source: Census of Manufacturers, 1963 and 1972 Fuels and Electric Energy Consumed (data is for SMSA level).

Table 12. ELECTRIC UTILITY FUEL USAGE IN CITY[a]

Fuel	Unit	1964	1973	Percentage difference 1964-1973
Gas	10^6 ft^3	4	5,596	+ 140,000
Oil	1,000 bbl	-	-	
Coal	1,000 tons	136	-	- 100

[a]Source: Steam Electric Plant Factors Book, 1965 and 1974, National Coal Association, Washington, D.C. (data is for CITY level).

Reductions of particulate emissions due to emission controls on coal combustion and industrial processes have also occurred, though the reductions to date have probably not been as great as those due to fuel switching. A steel mill across the river in Kentucky applied emissions controls in 1971 and 1972, reducing their emissions from 6700 TPY to 35 TPY. The particulate emission reduction was apparent in the improved air quality in downtown Cincinnati. The two major power plants outside Hamilton County are installing electrostatic precipitators. By 1976, the Tanner Creek Power Plant will be down from 42,000 TPY in 1972 to an estimated 1450 TPY, and the Beckjord power plant will be emitting 1540 TPY as opposed to 33,300 TPY in 1972. The Miami Fort power plant in Hamilton County, it is estimated, will be emitting 420 TPY in 1977, down from 47,000 TPY in 1972. Since most of the emission controls in both industry and power plants are in the process of being added, the results of their particulate reductions cannot be observed for a while.

Solid waste disposal practices have changed since 1969, resulting in considerable emission reductions. Of four municipal incinerators operating in 1969, three have been closed and replaced by sanitary landfill and the fourth has adopted emission controls. Municipal incinerator emissions declined from 2533 TPY in 1969 to 634 TPY in 1974. There were over 1000 small industrial, commercial, and private incinerators in 1969, emitting 317 TPY of particulates. Many of these were closed down by a regulation which banned single chamber, direct fed incinerators, and have been replaced by compactors or new, properly controlled incinerators. Emissions from domestic, commercial and industrial incinerators were estimated to be 99 TPY in 1974. Open burning, which contributed 4829 TPY in 1969, has been eliminated.

REGULATIONS, ENFORCEMENT AND COMPLIANCE

Institutional Framework

The Division of Air Pollution Control in Cincinnati has three different scopes of jurisdiction. In the City of Cincinnati, the agency is responsible for the city's air quality and air pollutant emissions and enforces the Air Pollution Control Ordinance of the Municipal Code. Its enforcement activities include making inspections of facilities and incinerators, maintaining surveillance of sources of pollutants, and issuing summonses. The Division evaluates permit and variance applications, holds variance hearings, oversees pollution controls installation, and samples air quality.

Since 1957, the Division has been under contract to nine municipalities in the industrialized Mill Creek Valley to provide air pollution control services. This contract effort is known as the Intercommunity Air Pollution Control Program. The services provided are: making inspections of industries and visible emissions, investigating complaints, assisting industry in completing permit applications, and recommending corrective actions.[2]

Finally, since 1971, the Division has been under contract to the Ohio EPA to provide air pollution control services in the Southwestern Ohio Air Pollution Control area which is comprised of four counties - Hamilton, Butler, Warren, and Clermont Counties. The Division investigates complaints, operates the permit system, oversees control equipment installation, and monitors air quality in SWOAPC.[2]

Regulations

The City of Cincinnati adopted a smoke abatement program in the 1940's, then in 1969, changed and strengthened its air pollution control regulations. The State of Ohio adopted air pollution control regulations in

1973. The city's regulations are at least as stringent as the state's regulations. The regulations pertaining to particulates are summarized in the Appendix for the city (Table A-1) and the state (Table A-2).

An overview of the city and state regulations shows that many are the same and that the regulations are in general about average when compared with the regulations of most states in the nation.

The visible emissions regulation allows emissions of no greater than 20 percent opacity, except that visible emissions up to 60 percent opacity are allowed for no more than 3 minutes.

The emissions standards for industrial processes and for fuel combustion are shown in Figures A-1 and A-2. The allowable emissions from incinerators are 0.1 pounds per 100 pounds of charge for incinerators with a capacity equal to or greater than 100 pounds per hour, and 0.2 pounds for incinerators of less than 100 pounds per hour. These emissions standards, the same for both city and state, are about average when compared with those of other states. The city code dictates design and operation criteria for incinerators. Open burning, with certain exceptions, is prohibited by both city and state.

The city's and the state's regulations require reasonable measures to be taken to prevent dust from materials handling from becoming airborne. Dust emissions from buildings or outdoors operations, which are a nuisance, shall be controlled by sealing off the building or operation and ventilating and treating the discharge. The city, in addition, prohibits visible emissions beyond the lot line of the property where they originate.

The city specifies the sulfur content (no more than 1 percent by weight) and volatility of solid fuels and requires solid fuel dealers to be licensed.

The city issues permits to operate for up to 3 years and variances good for up to 1 year. Annual inspections by the Division are allowed. A new permit to operate is required if the process or equipment is modified.

Enforcement and Compliance

The City of Cincinnati originally had set its deadline for compliance for 1974 but adopted the state's compliance deadline of April 1, 1977, when the state regulations were adopted. The Division of Air Pollution Control estimates that more than 90 percent of the industries in the four-county SWOAPC region are presently in compliance with the state's regulations. The remaining number are undergoing changes and are expected to be in compliance by 1977. Among these are some of the larger sources in Hamilton County - several industries in the Mill Creek Valley and the Miami Fort power plant. Thus, the 1974 emissions inventory is not a good indication of what the emissions situation in 1977 is expected to be.

The Division of Air Pollution Control evaluates applications for variances and permits to operate and recommends courses of action to Ohio EPA which the state generally follows. The Division also advises Ohio EPA during adjudication hearings with industries and other sources.

The Division conducts inspections and maintains surveillance of air pollution sources in the city and throughout the four counties. Annual inspections are made of all sources required to have permits to operate. Small sources (less than 1 million Btu per hour input from burning gas or oil, or solid fuel-burning equipment in buildings of less than four families, or approved incinerators in one or two family residences) are not required to have permits. Sources reporting breakdowns are inspected to ensure than negligence is not responsible.

When a violation of the regulations is reported, a conference is held as soon as possible with the company or individual involved so that the problem

can be discussed and corrective actions worked out. If the company or individual does not meet the correction deadline, he is faced with court proceedings - municipal court for violators in the city, the mayor's court of the community in the IAPCP in which the violator is located for violators in these nine communities, or Ohio EPA for violators in the four counties but outside of Cincinnati and the nine communities. But the relations between industry and the Division of Air Pollution Control are good - industry wants to avoid bad publicity and a futile, time-consuming and costly court case - so that reasonable plans for corrective action can usually be worked out by the Division and the violator. The Division has rarely had to go to court and has never lost a case among those that did.

At present, the Cincinnati and Ohio regulations and program of enforcement are in the process of reducing particulate emissions and already have achieved, on the whole, a high degree of compliance. The impact of all emission reductions, however, will not be felt until the compliance deadline in 1977.

METEOROLOGY AND CLIMATOLOGY

Ambient TSP concentrations in Cincinnati are influenced by meteorological and climatological factors and these, in turn, are affected by the topography and location of the city which were discussed earlier.

Cincinnati lies in an area which frequently experiences poor dispersion conditions as shown in Table 13. Concentrations of TSP, as well as other pollutants, are likely to be higher on days when dispersion is poor, because pollutants are prevented from rising and mixing. Since the industrial areas of the city and the adjacent towns lie in valleys where inversions tend to occur, the effect of industrial particulate emissions is probably magnified. The highest TSP concentrations in the county are recorded in the industrial valleys. In general, it is not possible with

the available data to determine the separate effects of inversions and high emission rates on TSP concentrations in the valleys.

Table 13. FREQUENCY OF INVERSIONS (PERCENT OF TIME)

Winter	25
Spring	18
Summer	12
Autumn	17
Annual	18

Source: Proposed Implementation Plan for the Control of Particulates and Sulfur Oxides for the State of Ohio Portion of the NEIAQCR, 1970.

Correlation of TSP with Annual and Monthly Measures

Correlations of annual mean TSP concentrations at the Public Library from 1958 to 1974 with other annual measures were performed and the results are presented in Table 14. Similarly, the monthly mean TSP concentrations for several city sites in 1974 are correlated with other monthly measures in Table 15. The correlations in the two tables are discussed below. The correlations showing the expected relationship are indicated in the tables. Monthly and quarterly TSP means in 1974 are shown in Figure 11.

Measures of mixing height are related to dispersion conditions. Since TSP concentrations are affected by dispersion, they would be expected to be related to measures of mixing height. The 1974 monthly citywide TSP means were negatively correlated with the monthly mean afternoon mixing height - that is, higher monthly mean TSP concentrations tended to occur in months when the mixing height was lower.

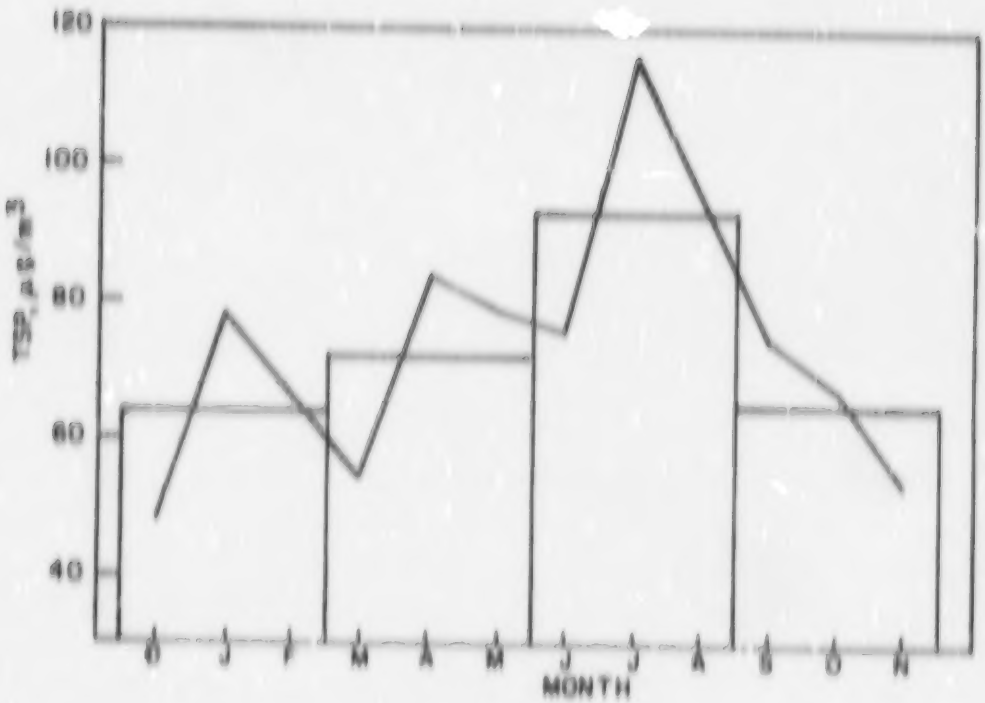


Figure 11. 1974 Monthly and quarterly citywide TSP means

Table 14. CORRELATION OF TSP TREND (ANNUAL GEOMETRIC MEAN) FROM 1958 to 1974 AT SITE 1, PUBLIC LIBRARY, WITH OTHER ANNUAL MEASURES

TSP versus time[a]	r = -0.025
TSP versus annual rainfall[a]	r = -0.309
TSP versus heating degree-days[a]	r = 0.255

[a]As expected.

Table 15. CORRELATION OF CITYWIDE MONTHLY TSP MEANS FOR 1974 WITH OTHER 1974 MONTHLY MEASURES

TSP versus monthly rainfall	r = 0.350
TSP versus heating degree-days	r = -0.688
TSP versus monthly mean afternoon mixing height[a]	r = -0.581

[a]As expected.

Cincinnati receives moderate amounts of rainfall, much of which occurs during the summer. Rainfall affects TSP concentrations because it tends to wash particulates out of the atmosphere and to suppress resuspension of dust. Precipitation trends are shown by year in Figure 12 and by month in Figure 13. The expected inverse relationship between rainfall and TSP concentrations was observed when comparing annual TSP with annual rainfall but was not observed between monthly TSP and rainfall in 1974. Precipitation affects TSP concentrations but it does not appear to be very important in determining TSP trends.

Cincinnati experiences moderately cold winters and averages about 5070 heating degree-days annually. Colder weather requires fuel burning for space heating purposes and thus results in greater space heating emissions during the winter months. Cincinnati's annual and seasonal patterns of degree-days are shown in Figures 14 and 15. Annual degree-day trends and TSP trends show a positive correlation, as expected, but seasonal patterns of degree-days and TSP concentrations in 1974 do not. It is possible that

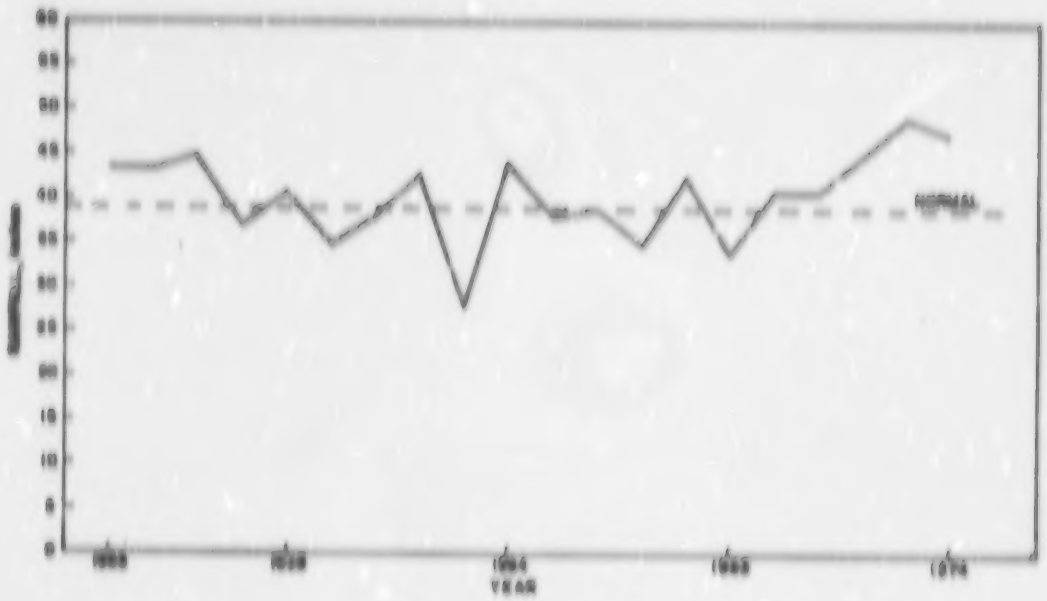


Figure 12. Yearly rainfall

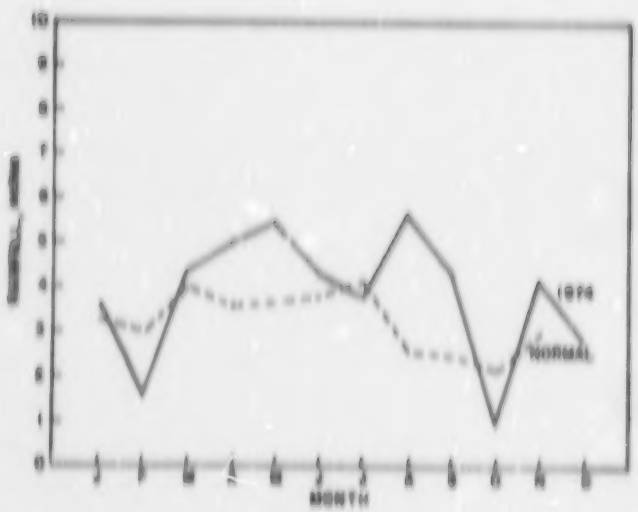


Figure 13. Monthly rainfall, 1974

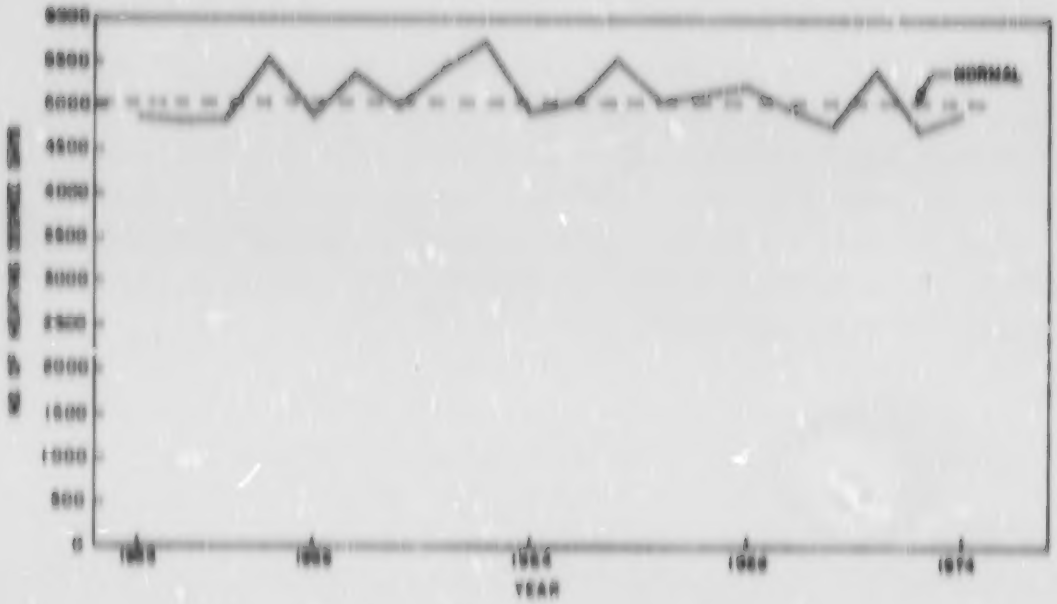


Figure 14. Yearly degree-days

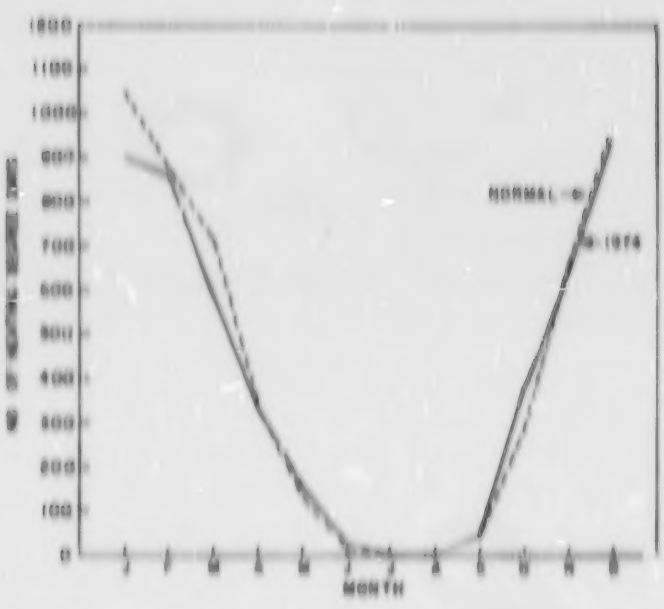


Figure 15. Monthly degree-days, 1974

the power plant in downtown Cincinnati, when burning coal in the years before 1966, was a major influence on the Public Library site so that annual degree-day trends and the corresponding fuel combustion trends would influence TSP concentrations and thus give a positive correlation. With most homes and utilities now using fuels other than coal, particulate emissions from space heating are low in comparison with other sources. Seasonal space heating emissions of particulates are therefore probably not significant and no positive correlation of TSP concentrations with degree-days would be expected.

Summarizing the annual and monthly measures which were correlated with TSP patterns, the annual TSP trend appears to be influenced by precipitation and degree-day trends but the seasonal TSP pattern in 1974 is influenced only by mean monthly afternoon mixing height. It appears that dispersion is an important influence on the seasonal TSP pattern.

Short-range and Long-range Transport

The annual prevailing wind in Cincinnati is from the southwest (see Figure 16). Westerly winds are also frequent during winter and spring. It is not possible to plot TSP concentrations as a function of wind direction because the available wind data is not considered representative of the actual winds occurring in the meandering valleys and along the bluffs. But TSP concentrations coming into the region are probably moderate due to the agricultural and generally rural character of the surrounding area. Two major point sources, the Miami Fort and Tanner Creek power plants, are located to the west-southwest of Cincinnati and might be impacting the city and its suburbs for a considerable amount of the time. Another source, a steel mill, located southwest of Cincinnati just across the river in Kentucky probably had a major impact on TSP concentrations in the city before it reduced its emissions in 1971 and 1972. The Beckjord power plant, another major source, is southeast of the city but probably influences TSP concentrations some of the time.

Figure 16. Annual wind rose for Cincinnati

Long-range meteorological factors also affect the area and TSP concentrations. During the summer, Cincinnati is influenced by the Bermuda High when warm, moist air from the western side of the Bermuda High sweeps up from the Gulf of Mexico over the Mississippi and Ohio River valleys. The incoming air masses tend to carry higher concentrations of TSP due to their trajectory over the southern states. During the autumn months, the region is affected by stagnating anticyclonic weather systems with low wind speeds - these systems cause persistent and severe inversions during which TSP and other pollutants tend to accumulate.

It appears, then, that while meteorological variables - rainfall, inversions, climate, weather systems, winds - influence TSP concentrations, they do not totally explain the TSP trends.

URBAN ACTIVITY FACTORS

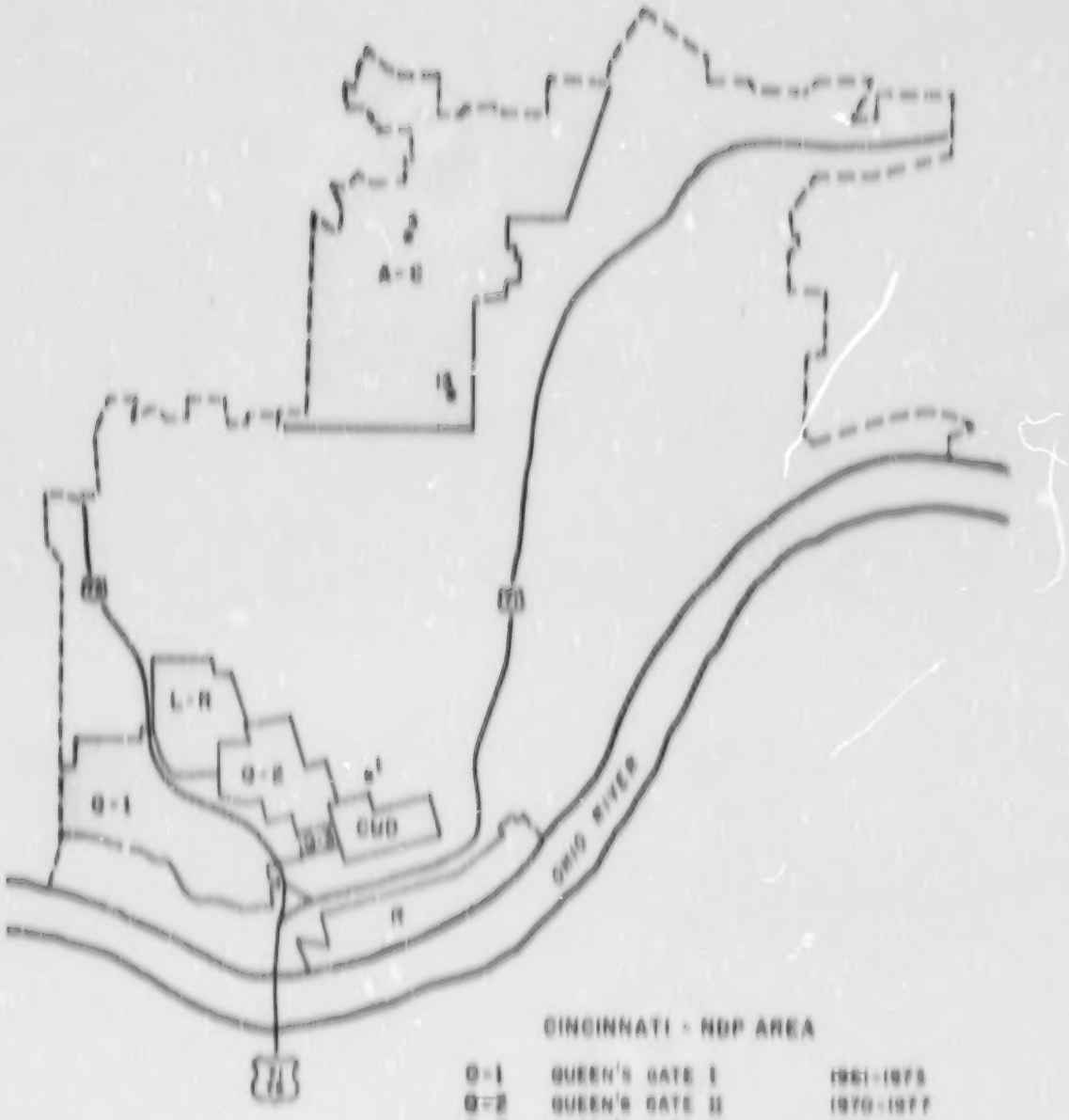
Construction Activity

For the past 15 years, an extensive urban development and highway construction program has been conducted in Cincinnati. Most of the construction activities have been occurring in the downtown area. Figures 17 and 18 show the locations of urban renewal areas and highways with respect to the monitoring sites.

Urban renewal and highway construction activities include demolition of structures, land clearing, construction of new buildings, roads and bridges, and rehabilitation of older buildings. All of these activities generate particulates and have been contributing to total particulate emissions, thus influencing the TSP concentrations in the city.

The monitoring sites closest to areas of construction activity are sites 1, 3, 4, 13 and 33. The highway construction and urban renewal activities and the annual TSP means are summarized for each site in Table 16. Several

Figure 17. Urban renewal and highways in Cincinnati



CINCINNATI - NDP AREA

Q-1	QUEEN'S GATE I	1961-1973
Q-2	QUEEN'S GATE II	1970-1977
Q-3	QUEEN'S GATE III	1965-1966
L-R	LAUREL RICHMOND	1957-1961
R	RIVERFRONT	1965-1976
CBD	CENTRAL BUSINESS DISTRICT	1965-1976
A-C	AVONDALE - CORRYVILLE	1961-1976

Figure 16. Cincinnati - NDP area

Table 16. [illegible]

Site number	Location	Year	Geometric mean TSP	Highway construction	Other research
1	Gilbertsville	1962	124		Shoreham (2.5 miles) — CBC (3.8 miles)
		1964	145		
		1965	133	I-95: Commercial to Court (3.0 miles)	Interchange
		1966	138		
		1967	111	I-95: Broadway to Commercial (3.0 miles)	
		1968	99	Route 3 Across Roads (3.0 miles)	
		1969	108		
		1970	102		
		1971	94		
		1972	87	Washington Viaduct, McCoy Bridge (3.0 miles)	
		1973	68		
		1974	71		
3	Avondale	1964	[illegible]	I-95: Hillsboro to Welsh (3.0 miles)	Avondale - Composite relationship (See Summaries) (since 1961)
		1965	82		
		1971	88	I-95: Welsh to Goodhues (3.0 miles)	
		1972	82		
		1973	72		
		1974	72		
4	Bailey	1964	–	Diamond Lateral, Montgomery to I-95 (3.0 miles)	
		1965	–	I-95: Hampton to Kennedy (7.0 miles)	
		1971	76		
		1972	77		
		1973	77		
		1973	65		
		1974	70		
10	Centerville	1964	–	I-95: Hillsboro to Welsh (7.0 miles)	Avondale - Composite relationship (See Summaries) (since 1961)
		1965	–		
		1971	67		
		1972	69		
		1973	66		
		1974	72		
11	Diamond	1970	–	Diamond Lateral, Reading to Montgomery (3.0 miles)	
		1971	–		
		1972	–		
		1973	74		
		1974	78		

[illegible] began at sites 3 and 4 in 1970, at sites 10 in 1971, and at sites 11 in 1972.

other monitoring sites (5, 6, and 12), are located near areas where construction took place but are not included because TSP data for those time periods are not available. It is apparent from the table that, even for these five sites, most of the construction activities have occurred quite a distance away from any one site (from 2000 to 5000 feet).

Two sites, sites 3 and 13, are surrounded by the Avondale-Corryville rehabilitation area. It is not possible to determine the effects of urban rehabilitation on the two monitors since the rehabilitation activities have been occurring before and ever since monitoring began at the two sites sites. The activities, however, are most likely contributing to the high urban TSP concentrations observed at the two sites.

The only instance where the effects of construction activities on TSP concentrations seem to be observed is at site 1, the Public Library. Work in the Riverfront, Queensgate III, and CBD urban renewal areas (see Figure 18) involved demolition of numerous structures from October 1964 through 1966. Annual geometric mean TSP concentrations jumped from 116 $\mu g/m^3$ in 1963 to 145 $\mu g/m^3$ in 1964, remained near that level for 1965 and 1966, and dropped off to 111 $\mu g/m^3$ in 1967. The effect on site 1 of nearby and frequent demolition of structures appears to be an additional 25 to 30 $\mu g/m^3$ on the annual geometric mean TSP concentration.

Urban renewal and highway construction activities have probably been contributing to high TSP concentrations at various monitors for the past 15 years and will continue to do so for the next few years. The distance of most of the monitoring sites from the construction areas, however, precludes precise measurement of the construction effect. In addition, there has been insufficient TSP data over time to study the effects of construction activities.

Land Use and Traffic Activity

The pattern of land use in Cincinnati is influenced by the Ohio River and the Mill Creek Valley. The central part of the city is located on a bend in the Ohio River. Land use becomes increasingly suburban and less dense farther from the CBD. Industry is concentrated mostly in the Mill Creek Valley from the northern part of the county to the Ohio River and in the Norwood Trough which stretches eastward from St. Bernard through Norwood. TSP concentrations tend to follow the land use patterns, being highest in the Mill Creek Valley and high in the center city and urban areas (see Figure 19). The predominant land use character of the sampling sites is summarized in Table 17 with the averaged 1974 TSP means. The four industrial sites averaged 104 $\mu g/m^3$ TSP in 1974. The center city site recorded a 1974 mean of 75 $\mu g/m^3$, the annual primary standard. The commercial and residential sites averaged about the same, 67 $\mu g/m^3$, which is between the annual standards.

Table 17. TSP VERSUS LAND USE

Predominant land use	Average of 1974 TSP means	Sites
Center city	75	1
Industrial	104	5, 6, 12, 15
Commercial	68	4, 27
Residential	67	2, 3, 7, 8, 13, 16, 33, 38, 39

Average daily traffic data are available for several of the sampling sites in the city (see Table 18). No correlation could be found between ADT and the 1974 geometric mean TSP concentration. The distance between the monitor and the street on which traffic data was taken was rather large for several of the monitors, thus reducing the ADT per unit of plant distance. But the primary reason for the lack of correlation between traffic counts and TSP concentrations appears to be that the land use and total associated

Figure 19. Land use patterns

activities surrounding a site are more important than the individual activity of traffic.

Table 18. TRAFFIC COUNTS AND TSP

Site	Street	Slant distance	ADT both directions	ADT/ slant distance[a]	1974 TSP geometric mean
2	Hamilton	250	21,000	84	57
4	Madison	200	22,000	109	70
	Marburg	200	10,000	50	70
6	Vine	51	14,000	274	95
7	Glenway	16	18,000	1,097	65
12	Vine	275	12,500	45	130
13	Taft	51	23,000	443	72
15	Beekman	76	12,000	157	92
33	Sherman	25	17,900	710	78
	Montgomery	300	36,300	121	78

[a]Correlation between ADT/slant distance and 1974 TSP geometric mean: $r = 0.149$.

NETWORK DESIGN AND MONITOR SITING

The sampling sites are located throughout Hamilton County and represent the various kinds of land development in the area. The locations of the sampling sites are shown in Figure 3 and information about them is summarized in Table A-3 in the Appendix. The center city is represented by the site at the Public Library (site 1), residential and commercial areas by sites in Cincinnati, Wyoming, Sharonville, Monfort Heights, Carryville, Forest Park, the East End, Harrison, Newtown, Madeira, Forrestville, Fairfax, Norwood, and St. Bernard (sites 2 to 4, 7 to 10, 13, 14, 16, 31, 24, 27, 29, 30, 33, 38 and 39), and industrial areas by sites in Lockland, Carthage, St. Bernard, Fairmount, and Addyston (sites 5, 6, 12, 15 and 19). Industry tends to be concentrated along the Mill Creek and the Norwood trough.

The design of the network is adequate for recording the variety of air quality situations in the county. The sampling sites are spread out in the areas farthest from the city, becoming more numerous and closer together in the city, its suburbs, and the industrial areas. There is no sampling site, however, that could be considered to be measuring background levels of TSP. The sampling sites farthest from the city appear to be located in residential or commercial areas of suburban towns.

The specific siting of the hi-vol monitors also seems to be generally adequate. Twelve of the 25 sites in Hamilton County were visited in order to assess hi-vol exposure and possible local sources which could be influencing the TSP concentrations which were recorded. The site characteristics are summarized in Table 19. These sites were assumed to be representative of the monitoring sites in the county. The exposure of the monitors is generally good, without obstructions by the building on which the monitor is located or other surrounding buildings. The heights of the monitors are also generally adequate, neither so low that they are affected predominantly by immediately local ground-level sources nor so high that a significant decrease in particulate concentrations might have occurred due to the height. Most of the monitors are in the 12 to 30 foot height range which is desirable for consistency between monitors. The Public Library monitor is the highest (80 feet) since CBD sites are usually difficult to place; this monitor has been operated the longest of any of the sites in the four county area and its placement is typical of NASN practices in the past. The elevation above the Ohio River of the monitors appears to influence TSP concentrations through the effects of inversions and channeling of wind in the valleys and the patterns of land use, wherein the industrial and central city areas are located in the valleys. The higher sites recorded the lower 1974 geometric mean TSP concentrations and vice versa. The two sites in St. Bernard, an industrialized town, are an example of the effect of elevation - the St. Clement's School monitor is one-half mile from the industrial area where the other monitor is located but it is 100 feet higher and recorded a 1974 mean of 76 $\mu g/m^3$ as opposed to 130 $\mu g/m^3$ at the other site.

Table 19. [illegible]

Site number	Location	[illegible] generic mean	Predominant influence	Elevation (feet)	Height (feet)	Land use
1	Public Library	75	CBD	550	10	Commercial - surrounding; other mixed uses - 1/4 mile S and W
2	College Hill Fire House	57	Residential	900	30	Residential - surrounding; Mill Creek Valley - 1 mile SE
4	Dalton Fire House	78	Commercial	550	35	Residential and commercial - surrounding; uptown parking lots nearby; Industry - 1/4 mile E and W
5	Lockland	100	Industrial	540	20	Industry (paper, narrows, chemical) - 1/4 mile S, SE; Commercial - surrounding
6	Carthage Fire House	95	Industrial	720	25	Residential - surrounding; I-75 - 2700 mile E; Industry - 1/4 mile NE, 1 mile SW
7	Price Hill Fire House	65	Residential	890	25	Residential - surrounding
8	Wyoming	74	Residential	750	12	Residential - surrounding
12	St. Bernard	120	Industrial	530	16	Industry (chemical, shipping) - surrounding; I-75 - 1/4 mile NE
13	Cunningville	72	Residential	800	35	Residential - surrounding
15	Fairmount	92	Industrial	550	25	Industry (foundry, railroad) - surrounding
38	Dixie Hospital	71	Residential	540	15	Residential - surrounding
39	St. Bernard, St. Clement's School	76	Residential	600	40	Industrial - 1/2 mile N; Residential-surrounding

IMPLEMENTATION PLANNING

Institutional Framework

The air pollution control program in the four county Southwestern Ohio Air Pollution Control area has been run by the Division of Air Pollution Control of Cincinnati under contract to the Ohio Environmental Protection Agency since 1971. Prior to that time, the Division of Air Pollution Control was responsible only for air quality within the city. It also provided air pollution control services to nine municipalities in the industrialized Mill Creek Valley under the Intercommunity Air Pollution Control Program.

The City of Cincinnati has had air pollution control regulations since the 1890s and has had a program of enforcement since the 1940s. Within the Intercommunity Air Pollution Control Program, enforcement of the city's regulations has been the responsibility of the mayors of the municipalities. When the State of Ohio adopted air pollution control regulations in 1972, these superseded all local regulations except those which were more stringent than the state regulations.

Under the present arrangement, the Division of Air Pollution Control provides air pollution control services to the four counties and advises the Ohio EPA on enforcement matters on the state level.

Implementation Planning Methodology

Measured TSP air quality was the basis for classifying Cincinnati as Priority I (see Figure 20). Cincinnati had prepared a control plan in 1967 using air quality diffusion modeling and this was used in the preparation of the Cincinnati demonstration region in the Ohio State Implementation Plan. The NEDS Emission Inventory of 1970 is given in Table 20 for comparison with the inventory used.

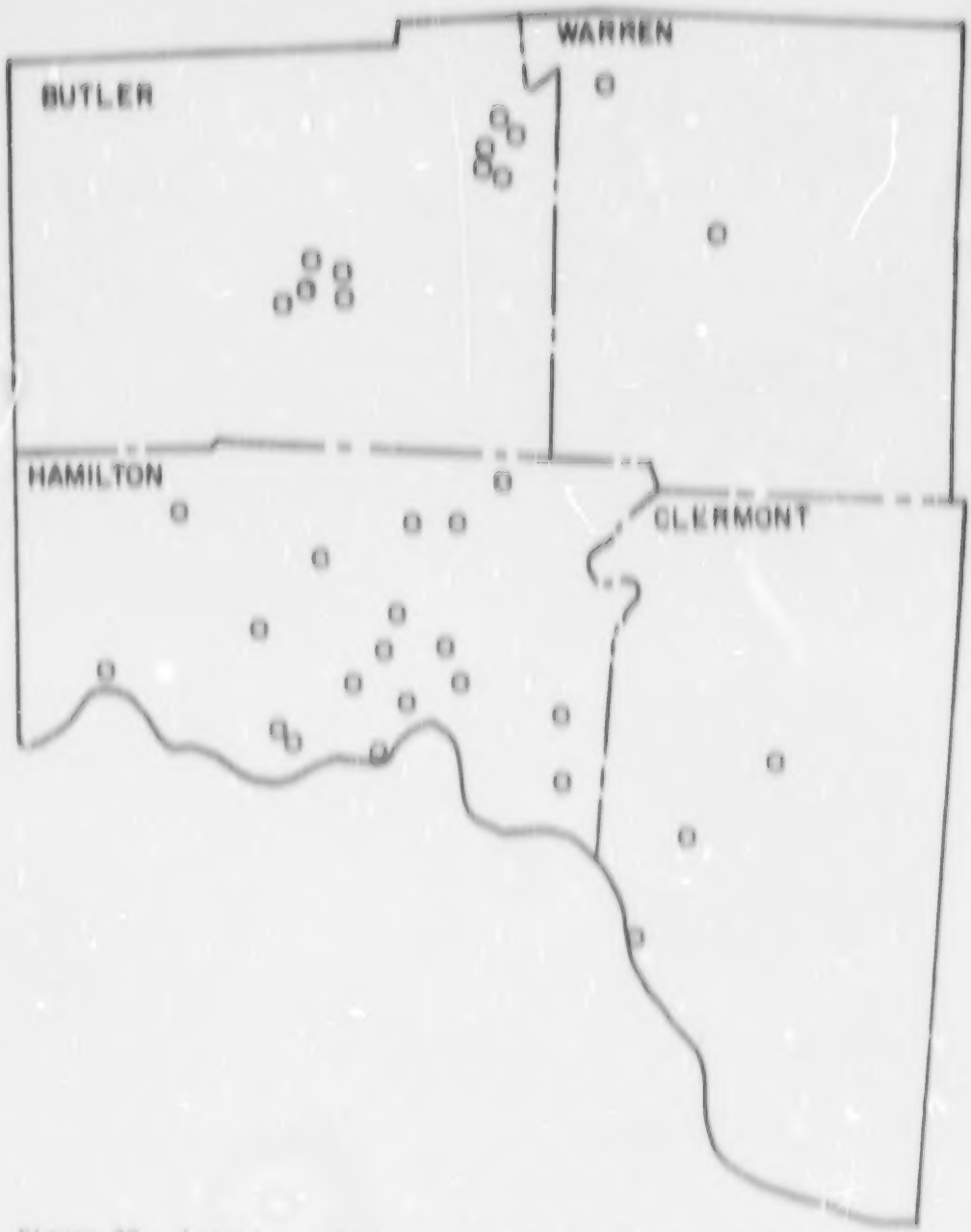


Figure 20. Locations of monitors used for determining priority classification of Cincinnati

Table 20. EMISSIONS INVENTORY SUMMARIES FOR PARTICULATES, 1970

Source category	Base data tonnes/yr (thousand short tons)	Standard data (thousand short tons)
I. Fuel combustion		
A. Residential fuel/area sources		
1. Coal	5,551	5,000
2. Distillate oil	150	150
3. Natural gas	614	1,000
4. Wood		
5. Other		
6. Total	5,871	6,000
B. Comm./instl. & industrial		
1-a Bituminous coal : area sources	11,051	10,000
1-b Bituminous coal : pt. sources	46,500	50,000
2. Lignite		
3-a Distillate oil : area sources	552	651
3-b Distillate oil : pt. sources	1	111
4-a Residual oil : area sources	65	65
4-b Residual oil : pt. sources	1	1
5-a Natural gas : area sources	565	677
5-b Natural gas : pt. sources	1	111
6-a Process gas : area sources		
6-b Process gas : pt. sources		
7-a Other : area sources	1,200	1,200
8. Total	60,144	100,000
C. Comm./industrial power plants		
1. Bituminous coal		
2. Anthracite coal	33,000	30,000
3. Distillate oil		
4. Residual oil		
5. Natural gas	111	10
6. Other		
7. Total	33,111	30,010
D. Total fuel combustion	131,111	110,101
II. Process losses		
A. Point sources	11,300	11,111
III. Solid waste disposal		
A. Incineration		
1-a On site : area source	2,701	2,000
1-b On site : pt. source		1,101
B. Open burning		
1. On site : area source	1,110	1,001
C. Total solid waste disposal	10,101	11,000
IV. Transportation : area source		
A. Motor vehicles : gasoline	1,000	1,100
Motor vehicles : diesel	11	100
B. Off highway fuel usage		
1. Aircraft	111	1,111
2. Railroad	11	11
3. Vessels	11	100
F. Gasoline handling area. losses		
G. Other		
H. Total transportation	1,001	2,111
V. Miscellaneous : area sources		
A. Agricultural burning		
B. Wildfires		
C. Total miscellaneous		
VI. Grand totals		
A. Area source	17,101	111,111
B. Point source	101,111	110,111
C. Total	110,000	111,110

The State of Ohio used the AQDM (air quality display model) or "worst region" approach in preparing the SIP. Three demonstration regions - Dayton, Zanesville and Cleveland - were chosen for the three priority levels and each was modeled. Each of the three regions was to be representative of other regions in its priority level. Cleveland was selected as the worst region for particulates based on existing ambient air quality data. The air quality data was obtained from monitors located in the areas of highest concentrations and the emissions data was obtained from the 1970 NEDS Emission Inventory (see Figure 21 and Table 20). Regulations which achieve the desired air quality in this region should therefore also achieve the standards in Cincinnati and the other Priority I regions.

The emission reductions necessary to meet the air quality standards were determined by proportional reductions. The highest TSP concentrations in Cleveland were an annual geometric mean of 77 $\mu g/m^3$ and a 24-hour value of 658 $\mu g/m^3$. Based on the highest annual value, proportional reduction calculations indicated that a 73 percent reduction in particulate emissions would be necessary to attain the Federal primary standard and an 87 percent reduction for the secondary standard (see Table 21). Proportional reductions to meet the daily standards were not as high as those based on the annual value.

Resulting Regulations

Based on the work done in 1970 using diffusion modeling in the Cleveland Region, a regulation requiring strict control of combustion sources, especially large units, and an increasingly restrictive degree of control for larger industrial processes was developed (see Figures A-1 and A-2). The regulations were adopted January, 1972, for Priority I regions.

Estimation/Projection Methodology

The regulations were applied to all point sources in the Cleveland Region and reduced emissions were tabulated. Estimates of area source emission

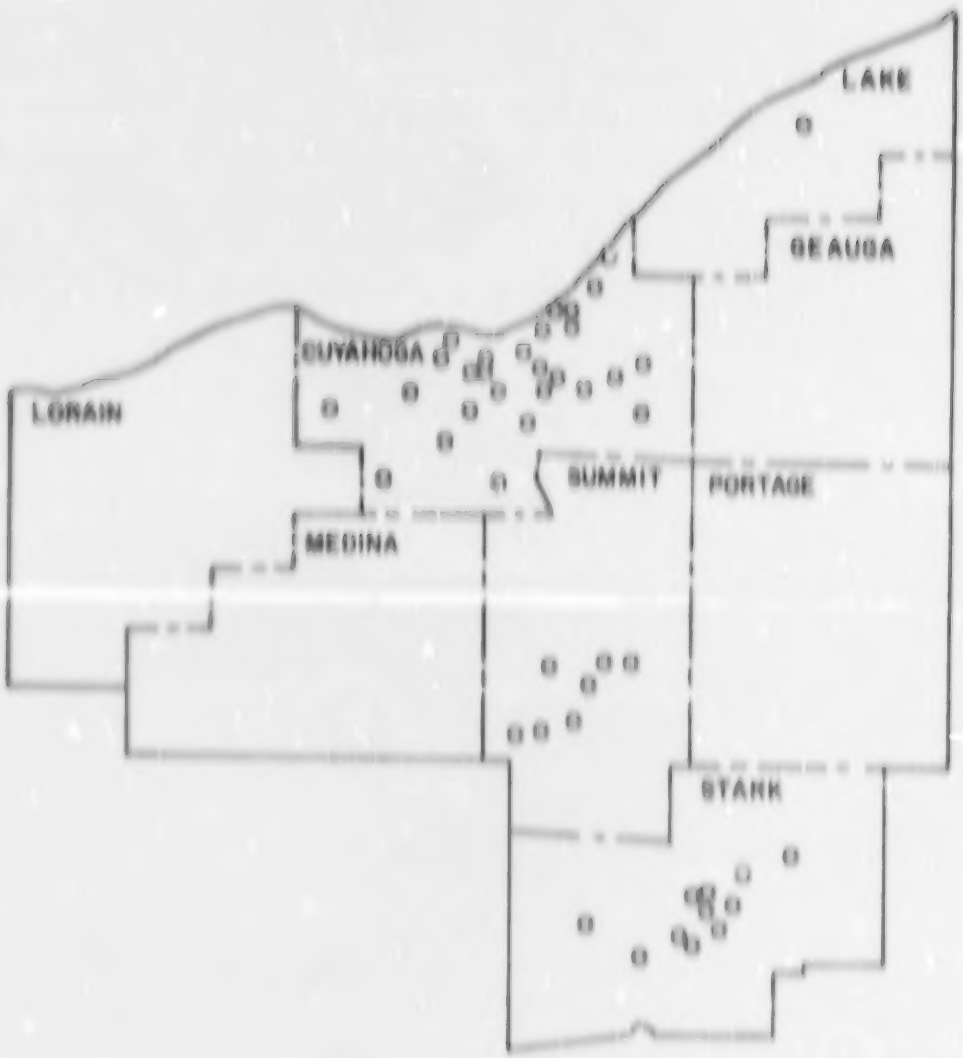


Figure 21. Locations of monitors used for determining the priority classification of the metropolitan Cleveland AQCR

Table 21. CLEVELAND AND OTHER PRIORITY I REGIONS — REQUIRED EMISSION REDUCTIONS

Air quality standard $\mu g/m^3$		Maximum measured concentration $\mu g/m^3$		Required emission reductions[a]		Existing emissions ($x10^3$ TPY)	Emissions required to meet standards ($x10^3$ TPY)		Estimated emissions after applying controls ($x10^3$ TPY)
Annual geometric mean	24 hr	Annual geometric mean	24 hr	Primary	Secondary		Primary	Secondary	
60	150	225	658	79%	87%	371	60	36	54

[a]Calculated by $\frac{(A-C)}{(A-B)}$ 100 based on annual average. (A = measured concentration, B = background (35 $\mu g/m^3$), C = desired level (standard)).

$\frac{225 - 75}{225 - 35}$ (100) = 78.95 percent

$\frac{225 - 60}{225 - 35}$ (100) = 86.84 percent

reductions were also made based on the degree of control achieved by point sources. Applying the regulations and taking into account growth between 1970 and 1975, it was determined that emissions by 1975 would be about 80 percent below the 1970 emissions. Thus, it is assumed that the Federal primary standard can be met with the application of these regulations. Since calculations indicate that the Federal secondary standard cannot be achieved with the regulations, Ohio was given an extension to develop a sufficient control strategy for the Cleveland Region.

Using Cleveland as a basis for developing regulations for other Priority I regions probably resulted in regulations that were apparently stricter than necessary to achieve compliance in the other regions. And the situation in Cleveland which is considered a "worst case" is probably understated. The NEDS emissions inventory (Table 20) shows that 1970 total emissions were estimated to be greater than 270,000 tons per year in the AQCR. This is a large amount indeed but probably an underestimation since the local agencies do not have adequate inventories for either past or present, have not yet gotten all sources on file, and have not estimated area source emissions.

REFERENCES

1. A Modeling Study to Assess Attainment of the SO_2 and TSP NAAQS in the Cincinnati AQCR. Source Receptor Analysis Branch, MDAD of OAQPS. Environmental Protection Agency. December 1975.

2. Air Pollutant Emissions in Greater Cincinnati, 1972. Division of Air Pollution Control, Department of Sewers, City of Cincinnati.

SECTION III

SUMMARY AND CONCLUSIONS

SUMMARY

Air Quality Levels

Annual mean TSP concentrations in 1974 in Cincinnati and Hamilton County ranged from less than 60 ug/m^3 at three monitors in suburban areas to around 75 ug/m^3 at several sites in residential areas and over 100 ug/m^3 in the industrialized Mill Creek Valley. The annual primary standard was exceeded by seven of the 25 sites and the annual secondary standard was exceeded by 14 other sites. The 24-hour primary standard was exceeded by 0.1 percent of the samples and the secondary standard by 4.2 percent of the samples.

Air quality levels in Cincinnati are influenced by several factors, most important of which is the fact that Cincinnati is an industrial city. The different kinds and large volumes of manufacturing require a large amount of fuel combustion during which particulates are emitted. The major sources of particulates in the county are a coal-burning power plant and coal combustion and process emissions from industries. In addition, there are two major sources of particulates -- power plants -- which are nearby but outside the county limits. The sampling sites nearest the industrial areas (sites 5, 6, 12, and 15) recorded the highest TSP concentrations in the county.

An air quality modeling study performed by EPA for 1975 indicates that the sources most responsible for TSP concentration above background at certain city sites are area sources and fuel combustion point sources. There are no monitoring sites located near enough to any of the power plants to be able to record their effect on the local TSP air quality but it is possible that they are contributing to the high background levels seen in the EPA study.

The topography of the area is complex - the city is located in the Ohio River Valley and is surrounded by steep bluffs which are cut by streams and rivers and rise 200 to 600 feet to the level of the upland plain. The topography of the area influences both the meteorology and the land use patterns of the city which in turn influence the TSP concentrations recorded. The city, especially the valley areas, frequently experiences poor dispersion conditions, particularly in the summer and fall. The industrial areas of the county lie in the valleys, so that inversions which tend to occur in the valleys magnify the effects of industrial particulate emissions. The highest TSP concentrations in the county were recorded at the sampling sites in the densely and industrially developed valleys - the Mill Creek Valley (sites 5, 6, 12, and 15), the Norwood Trough (sites 4 and 13), and the Ohio River Valley (site 1).

The types of land use in the vicinity of the sampling sites also appear important in determining TSP concentrations. The industrial sites, averaged in 1974, had the highest annual TSP mean (104 $\mu g/m^3$), followed by the center city site (75 $\mu g/m^3$), and the commercial and residential sites (68 and 67 $\mu g/m^3$, respectively).

Cincinnati's meteorology and climatology also influence the TSP concentrations. Cincinnati has a moderate heating requirement, averaging 5070 heating degree-days per year, and requires a considerable amount of fuel combustion for space-heating which results in particulate emissions.

Air Quality Trends

Air quality has been improving for the past 10 years -- annual geometric mean TSP concentrations decreased 70 $\mu g/m^3$ at the NASN site in the center city. An average decrease of 10 $\mu g/m^3$ occurred from 1970 to 1974 at seven city sites.

Reductions in emissions have been responsible for the reductions in TSP concentrations over the past few years. Switching from coal to other fuels has been occurring in housing since the end of the last World War. Power plants and, to a lesser degree, industries have been switching fuels more recently. The importance of coal as a fuel is decreasing, but coal combustion still remains the major source of particulate emissions in the county.

The air pollution control regulations, most recently revised in 1969, have also been responsible for emission reductions. The regulations, which are considered about average, have been enforced vigorously. Most sources are presently in compliance and the remainder are expected to be in compliance by April 15, 1977, the deadline for compliance. Enforcement of the regulations has resulted in the closing or improvement of private and municipal incinerators, fuel switching, and emission controls. Improvements in air quality at the downtown NASN site (Public Library) were noticed after 1966 when the downtown power plant switched from coal to natural gas and again in 1971 and 1972 when a steel mill across the river in Kentucky applied emission controls.

A comparison of TSP trends with other trends showed that TSP was significantly correlated with time ($r = 0.825$) -- TSP concentrations have been decreasing over time. TSP was not correlated significantly with annual rainfall or heating degree-days ($r = 0.309$ and $r = 0.255$, respectively), though the direction of these correlations was as expected.

CONCLUSIONS

The historical air quality data available shows that air quality with respect to TSP exceeded the national annual standards in Cincinnati in the past. The high TSP concentrations were due to the highly industrialized character of the city, the extensive use of coal by industries and utilities and the poor dispersion conditions frequently experienced. The NASN site since 1966 and several center city and industrial sites since 1970 have shown decreases in annual mean TSP concentrations. This resulted from fuel switching by homes, utilities, and industries, the vigorous enforcement of the regulations by the Division of Air Pollution Control, and controls on industrial and incinerator emissions.

The sampling sites farthest from the city are meeting both annual standards while the suburban sites near the city are below only the annual primary standard. The center city and industrial sites, though they have experienced decreases in TSP concentrations due to decreasing emissions, continue to exceed the annual standards. The 24-hour primary standard was exceeded only twice in the county during 1976. Some major sources of particulate emissions are presently in the process of coming into compliance - emission controls are being installed and fuel switching is taking place. All sources are expected to be in compliance with the regulations by April 15, 1977, at which time the impact of full compliance on air quality can be measured, but is is likely that TSP concentrations, though lower, will continue to exceed the annual standards. Fugitive emissions and fugitive dust have not been inventoried or controlled and could be a considerable influence in the industrial valleys as shown by the model results and the sampling site descriptions. Poor dispersion is a relatively constant factor in Cincinnati, frequently confining pollutants in the valleys where most of the industrial activity is located.

APPENDIX A

SUPPLEMENTARY INFORMATION

Table A-1. AIR POLLUTION CONTROL ORDINANCE OF THE CINCINNATI MUNICIPAL CODE

Chapter 1005 - Ambient air quality standards for suspended particulates are set forth and are the same as the national secondary standards - the maximum annual geometric concentration shall not exceed 60 ug/m3 and the maximum 24-hour concentration of 150 ug/m3 is not to be exceeded more than once per year.

Chapter 1007 - This includes general emission standards and control regulations for the following:

Section 1 - Visible emissions darker than Ringelmann 1 or 20 percent opacity are not permitted. Emissions of a shade not darker than Ringelmann 3 or 60 percent opacity are allowed for up to 3 minutes in any 60 minute period.

Section 3 to 7 - Open burning is prohibited except under certain conditions. A permit is required.

Section 11 - Necessary precautions shall be taken to prevent particulate matter from becoming airborne during materials handling or construction.

Section 13 - Visible emissions beyond the lot line of the property on which they originate are prohibited.

Section 15 - If emissions from a building or equipment cause a nuisance, the superintendent may order sealing off, ventilating, and treating the discharge.

Section 17 - Emissions from building cleaning and repair are regulated.

Section 21 - Emissions from the spray application of riberated cementitious products are regulated.

Table A-1 (continued). AIR POLLUTION CONTROL ORDINANCE OF THE CINCINNATI MUNICIPAL CODE

Section 31 - Visible emissions from gasoline-powered motor vehicles for more than 5 seconds are not allowed. Visible emissions from diesel-powered motor vehicles, locomotives, and river boats and steam-powered locomotives and river boats of a shade darker than Ringelmann 1 or 20 percent opacity are allowed for no longer than 5 seconds.

Section 33 - Emissions from diesel motor buses are regulated.

Section 41 - Emissions of particulates from industrial processes are not permitted in excess of the amount shown in Figure A-1.

Section 55 - Emissions of any air contaminant which cause a nuisance are unlawful.

Section 59 - Scheduled maintenance or breakdown of equipment must be reported.

Chapter 1009

Section 1 - Emissions from incinerators shall not exceed 0.1 pounds per 100 pounds of charge for incinerators of capacities greater than or equal to 100 pounds per hour, or 0.2 pounds per 100 pounds of charge for incinerators of less than 100 pounds per hour capacity. The other sections of this chapter specify requirements for testing, operation, and controls.

Chapter 1011

Section 1 - Emissions of particulates caused by fuel combustion in fuel-burning equipment in excess of the quantity shown in Figure A-2 are not allowed.

Section 3 - Hand-fired fuel burning equipment which burns smokeless solid fuel smokelessly (i.e., less than Ringelmann 1 or 20 percent opacity) may be operated with a permit. The other sections of this chapter specify requirements for testing, operation, and controls.

Chapter 1015 - This regulates the sale and consumption of solid and liquid fuels.

Section 5 - The sulfur content of solid and liquid fuels shall not exceed 1.0 percent by weight. Fuel in excess of 1.0 percent sulfur by weight may be used if control equipment is installed so that emissions shall not exceed that which would occur if a fuel of 1.0 percent sulfur had been used.

Table A-1 (continued). AIR POLLUTION CONTROL ORDINANCE OF THE CINCINNATI MUNICIPAL CODE

Chapter 1017

Section 1 - Annual inspections of all facilities requiring a permit to operate shall be made. Solid or liquid fuel burning equipment under 1 million Btu per hour input, family dwelling units of 3 or less families, buildings with small furnaces, or approved incinerators are not subject to inspection or operating certificate.

Section 3 - Permits to construct or modify are required of any air contaminant source.

Section 5 - Permits to operate are required of any air contaminant source.

Section 7 - Violations of regulations are permitted only if a compliance schedule and a variance have been applied for and approved.

Chapter 1019 - This chapter deals with regulations for preventing air pollution emergency episodes.

Table A-2. REGULATIONS OF THE OHIO AIR POLLUTION CONTROL BOARD

AP-3-06 - Air Quality Control Regions in the state are classified according to priority (I, II, or III) based upon measured ambient air quality.

AP-3-07 - Visible emissions darker than Ringelmann 1 or 20 percent opacity are not permitted. Visible emissions not darker than Ringelmann 3 or 60 percent opacity are permitted for not more than 3 minutes in any 60 minute period.

AP-3-08 - Open burning of refuse is prohibited with certain exceptions.

AP-3-09 - Reasonable precautions shall be taken to prevent from becoming airborne particulate matter from materials handling transport or storage, or the use, construction, or demolition of buildings or roads. If emissions from a building or equipment cause a nuisance, the Board may order sealing off, ventilating, and treating the discharge.

AP-3-10 - Emissions from incinerators shall not exceed 0.1 pounds per 100 pounds of charge for incinerators of greater than or equal to 100 pounds per hour, or 0.2 pounds per 100 pounds of charge for incinerators of less than 100 pounds per hour capacity.

AP-3-11 - Emissions of particulates caused by fuel combustion in fuel-burning equipment in excess of the quantity shown in Figure A-2 are prohibited.

AP-3-12 - Emissions of particulates from any source in excess of the amount shown in Figure A-1 are prohibited.

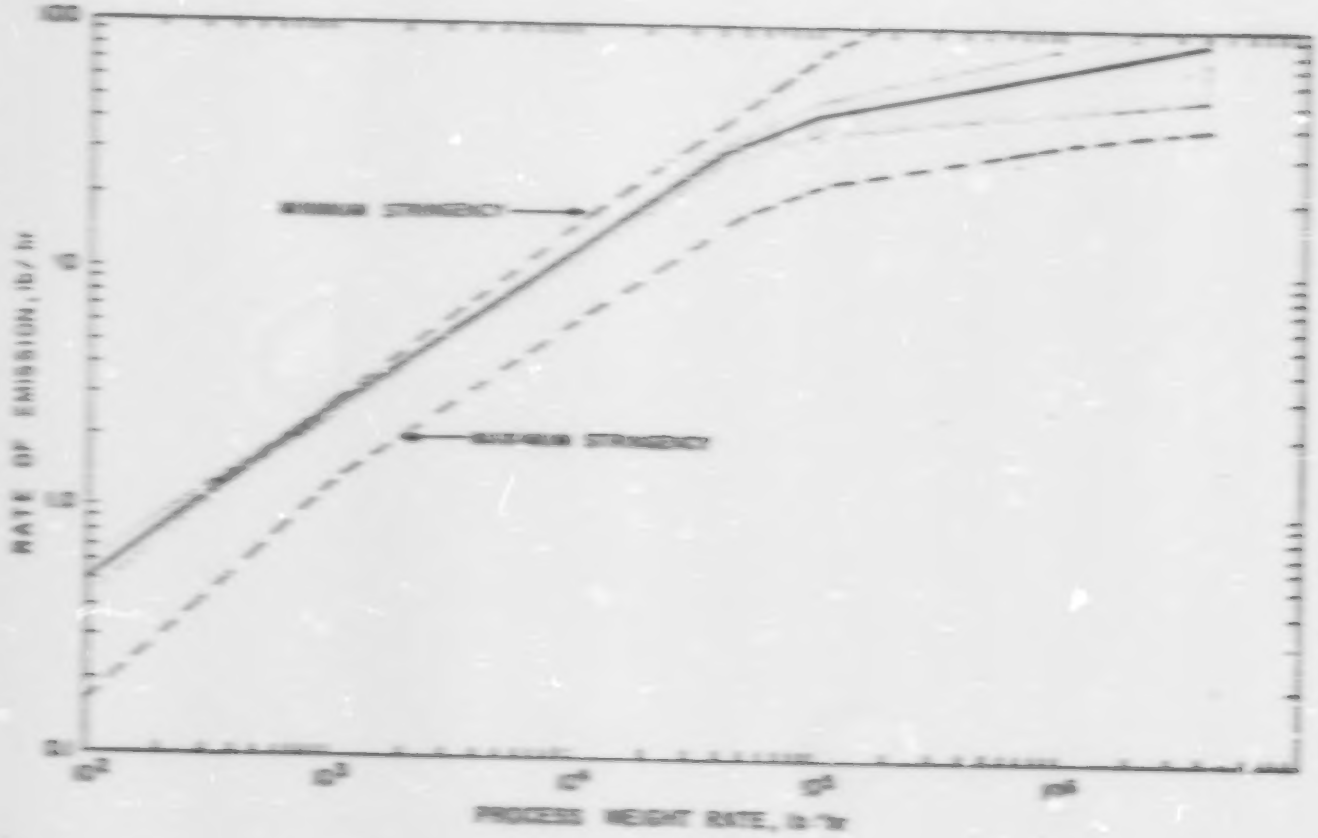


Figure A-1. Process weight regulation for Cincinnati and the State of Ohio

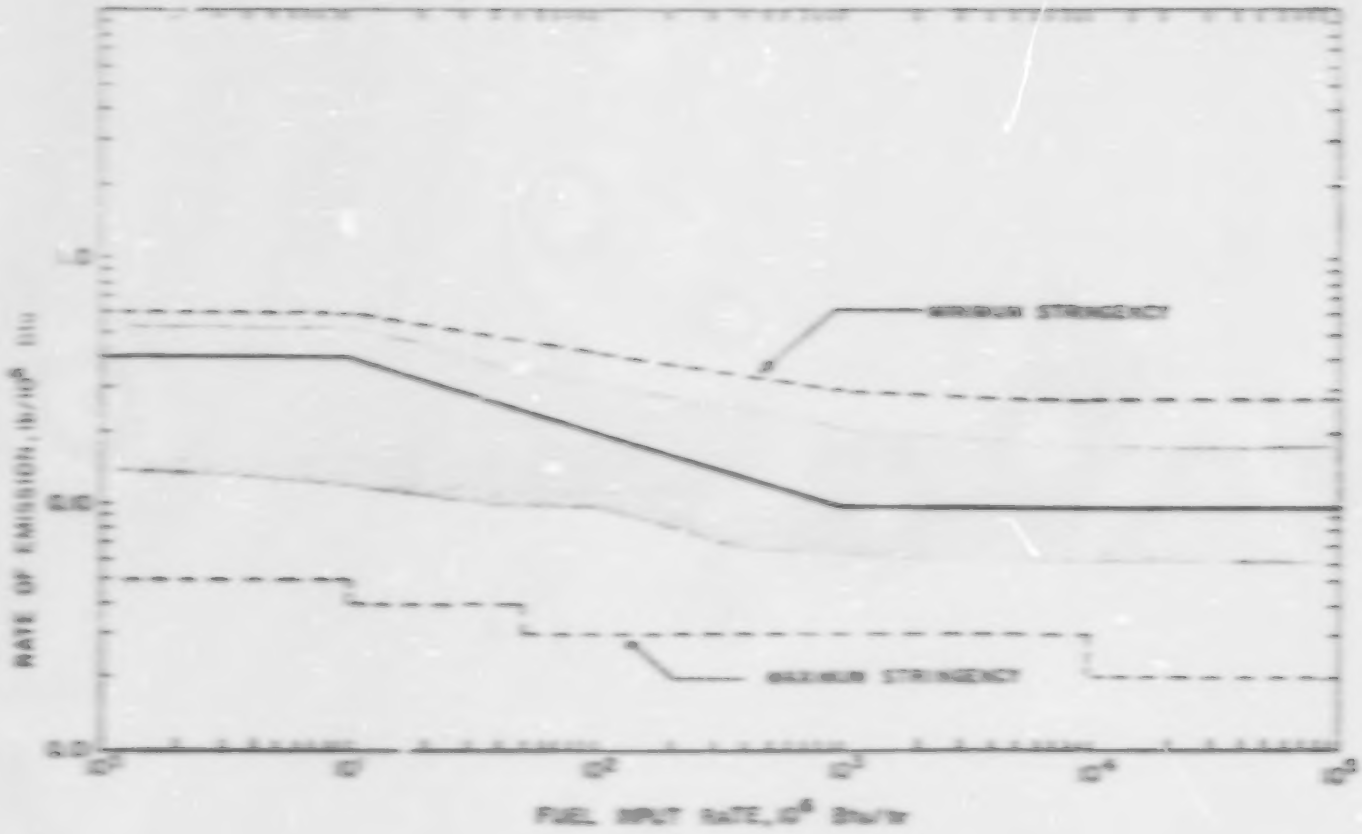


Figure A-2. Fuel combustion emissions regulation for Cincinnati and the State of Ohio

Table A-1. SAMPLING SITE INFORMATION

Table A-3 (continued). SAMPLING SITE INFORMATION

[illegible] code	Sample code	City	County	Address	Elevation		Characteristics	Height (feet)	Years	Remarks
					Sampling	Surveying				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX B

PARTICLE CHARACTERIZATION

For most of the study cities, members of the GCA study team acquired hi-vol filters from the 1974 filter banks of the cognizant local agencies. In addition, several filter samples for 1974 and selected earlier years were obtained from state and federal filter banks. Although some filters underwent chemical and/or detailed physical analysis, the principal purpose of obtaining filters was to utilize optical microscopy to identify each of the constituents that comprised more than 5 percent of the particulate mass. The selected filters, which were representative of several different site types and TSP levels within each study area, were returned to a clean room at GCA/Technology Division and carefully inspected for artifacts and evidence of sampler or filter malfunctions.

Each filter was then assigned a randomly generated five digit number which served as the only identifier for the filter sample so that each analyst had no information concerning the city, site, TSP loading or probable local sources associated with the sample. Furthermore, the use of two laboratories for the microscopy, coupled with the randomly generated identifying numbers, permitted a fairly comprehensive quality control program in the form of blind replicate analyses. Since both laboratories utilized more than one analyst, these procedures resulted in as many as four microscopists observing samples from the same filter and, in some cases, the same analyst examining replicate samples from the same filter as many as three times.

The results of this quality control effort, which are presented in Volumes I and II, warn against relying very heavily on the results of any one filter analysis. However, the random match-up between analyst and filter sample should minimize systematic bias in composited results.

Twenty filters from four sites were selected for analysis in Cincinnati and the meteorological data from the Greater Cincinnati Airport for the selected sampling days are summarized in Table 8-1. To gain some insight into the contribution of secondary particulates, much of which is too small to be observed by the microscopists, the annual average sulfate and nitrate concentrations for the NASN site are shown in Table 8-2. The results for each of the filters submitted for routine analysis are presented in Table 8-3. The results for the filters at each site have been averaged to give a composite of the particulate composition as shown in Table 8-4. Five filters underwent replicate analyses, and the results are presented in Table 8-5.

The composite particulate characterization for all filters from Cincinnati that underwent routine analysis, presented in Table 8-6, shows that minerals predominate but that there is nearly an equal contribution from combustion products. In fact, Cincinnati had the highest average percent contribution of combustion products of all 16 study cities. A large portion of the combustion products is coal related (glassy fly ash, coal soot) which is reflective of the large industrial and utility use of coal.

It is somewhat perplexing that the site at the highest elevation above grade also had the highest average rubber content. Although the citywide average percent rubber was low compared to most other study cities, the Public Library site, which is 80 feet above grade, experienced as much as 20 percent rubber on one selected sampling day.

Table B-1. METEOROLOGICAL DATA ON SELECTED SAMPLING DAYS (GREATER CINCINNATI AIRPORT)

Date	Precipitation, in.		Wind speed, mph		Wind direction, deg	
	Day of obs.	Preceding day	Average	Resultant	3-hour obs.	Resultant
7/16/74	0	0.74	7.2	5.1	60, 70, 50, 90 30, 30, 50, 90	60
7/28/74	0	0	3.0	1.9	0, 230, 220, 210 260, 220, 260, 0	230
8/13/74	0	0	6.8	3.8	50, 70, 80, 140 80, 120, 140, 120	100
10/08/74	0	0	5.0	1.2	50, 30, 60, 100 330, 160, 190, 210	180
10/26/74	0	0	5.5	3.5	30, 10, 40, 30 10, 310, 0, 210	20
12/31/74	0.43	t	8.2	1.8	70, 90, 100, 120 100, 280, 270, 290	160

Note: 0 = Data
t = Trace

Table B-2. ANNUAL AVERAGE CONCENTRATIONS OF SULFATE AND NITRATE IONS AT THE CINCINNATI, OHIO, NASN SITE NO. 361220001 ($\mu g/m^3$)

Year	Sulfate		Nitrate	
	Arithmetic mean	Geometric mean	Arithmetic mean	Geometric mean
1972	11.98	11.36	3.71	3.54
1973	11.37[a]	10.63[a]	3.15[a]	2.78[a]
1974	12.62[a]	11.50[a]	3.67[a]	3.16[a]

[a]Indicates insufficient data for statistically valid year.

Table B-3a. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CINCINNATI AND VICINITY (PUBLIC LIBRARY — NO. 1)

Table B-3b. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CINCINNATI AND VICINITY (ATOMIC ELEMENTARY SCHOOL — NO. 8)

Date	24 July 1964			28 July 1964			13 August 1964			9 October 1964			15 October 1964			17 December 1964		
Time (EST)	10			10			10			9a			10			10		
Constituent	Concentration, counts/min	Size range, μ	Avg. size, μ	Concentration, counts/min	Size range, μ	Avg. size, μ	Concentration, counts/min	Size range, μ	Avg. size, μ	Concentration, counts/min	Size range, μ	Avg. size, μ	Concentration, counts/min	Size range, μ	Avg. size, μ	Concentration, counts/min	Size range, μ	Avg. size, μ
Beryllium	(1+)			(1+)			(1+)			(1+)			(1+)			(1+)		
Boron	2+	1–10	5	2+	1–10	5	2+	1–10	5	2	1–10	5	2+	1–10	5	1	1–10	5
Calcium	1	1–10	5	1	1–10	5	4	1–10	5	3	1–10	5	4	1–10	5	1	1–10	5
Cerium	1	1–10	5	1+	1–100	30	1	1–10	5	1	1–10	5	1	1–10	5			
Cesium-137	(1)			(1+)			(1)			(1+)			(1)			(1+)		
Chromium																		
Cobalt	1	1–10	5	1	1–10	5	1	1–10	5	1+	1–10	5	1+	1–10	5	1	1–10	5
Copper	2	1–100	5	1+	1–100	30	1	1–10	30				1+			2	1–10	30
Europium-152																		
Europium-154																		
Europium-155																		
Gadolinium-159																		
Gallium-72																		
Gold-198	(1+)			(1+)			(1+)			(1+)			(1+)			(1+)		
Iodine-131																		
Iron-59																		
Lanthanum-140																		
Lead-203																		
Manganese-54	(1+)			(1+)			1+			(1+)			(1+)			(1+)		
Mercury-203																		
Molybdenum-99							1+	1–10	30									

Table B-1:. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CINCINNATI AND VICINITY (ST. BERNARD — NO. 12)

Date	14 July 1954			28 July 1954			11 August 1954			8 November 1954			26 October 1954			21 December 1954		
Air ($\mu g/m^3$)	270			324			272			240			178			84		
Components	Quantity, micrograms	Size range, μ	Avg. size, μ	Quantity, micrograms	Size range, μ	Avg. size, μ	Quantity, micrograms	Size range, μ	Avg. size, μ	Quantity, micrograms	Size range, μ	Avg. size, μ	Quantity, micrograms	Size range, μ	Avg. size, μ	Quantity, micrograms	Size range, μ	Avg. size, μ
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
[illegible]	[illegible]			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
[illegible]				[illegible]									[illegible]			[illegible]		
[illegible]	[illegible]																	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]																		
[illegible]	[illegible]			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
[illegible]													[illegible]					
[illegible]	[illegible]			[illegible]			[illegible]			[illegible]						[illegible]		
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[illegible]																		
[illegible]	[illegible]			[illegible]			[illegible]			[illegible]			[illegible]			[illegible]		
[illegible]																		

Table B-31. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN CINCINNATI AND VICINITY (COLLEGE HILL FIRE HOUSE — NO. 2)

Date,	[illegible]			[illegible]		
Air ($\mu g/m^3$)						
Constituents	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
[illegible]				[illegible]	[illegible]	[illegible]
[illegible]				[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]		
[illegible]						
[illegible]				[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]			[illegible]		
[illegible]						
[illegible]						
[illegible]						
[illegible]						
[illegible]	[illegible]			[illegible]		
[illegible]				[illegible]		
[illegible]				[illegible]		

Table B-4. COMPOSITE SUMMARY OF FILTER ANALYSES FOR SELECTED SITES IN CINCINNATI AND VICINITY

Site	Public Library - No. 1		St. Bernard No. 12		Wyoming Elem. School - No. 8		College Hill Fire House - No. 2	
No. of filters	6		6		6		2	
	Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent	
Components	Average	Range	Average	Range	Average	Range	Average	Range
Minerals	(36)	25-43	(36)	28-48	(65)	25-81	(52)	15-89
Quartz	15	8-25	20	5-41	20	10-25	11	6-15
Calcite	16	5-26	26	11-38	28	10-50	26	5-45
Feldspars	6	4-10			3	2-3	5	2-8
Hematite	1	<1-2	5	1-16	14	3-45	6	3-9
Mica	Tr	0-1					<1	
Other	Tr	0-Tr	1	0-4				
Combustion Products	(53)	39-68	(61)	9-69	(33)	17-75	(56)	37-84
Soot:								
Oil	8	5-12			20	10-32	3	0-10
Coal	12	0-20	4	4-4	2	1-2	6	2-10
Very fine	1	0-1						
Unidentified soot			1	0-8				
Glassy fly ash	20	2-50	36	1-68	11	1-20	41	15-65
Incinerator fly ash	12	0-40			<1			
Burned wood					<1	0-1		
Burned paper					<1			
Magnetite	<1	0-1					4	0-8
Biological Material	(1)	Tr-3	(1)	<1-1	(<1)		<1	
Pollen	Tr	0-Tr	Tr	0-Tr	Tr		<1	
Spores			Tr	0-Tr	Tr		<1	
Paper	Tr	0-Tr	Tr	0-Tr	Tr		<1	
Starch	<1	0-1	<1		Tr		<1	
Misc. plant tissue	1	Tr-3	<1	0-1	Tr		<1	
Miscellaneous	(10)	Tr-20	(3)	<1-3	(2)	<1-5	(2)	<1-5
Iron or steel	<1	0-1	<1		<1		<1	
Rubber	10	Tr-20	3	0-3	2	<1-5	2	0-5

Table B-6. CITYWIDE COMPOSITE SUMMARY OF FILTER ANALYSIS IN CINCINNATI

No. of filters	20	
	Quantity, percent	
Components	Average	Range
Minerals	(51)	24-89
Quartz	19	5-63
Calcite	22	5-50
Feldspars	3	0-10
Hematite	6	<1-45
Mica	<1	
Other	<1	
Combustion Products	(44)	9-84
Soot:		
Oil	9	0-52
Coal	6	0-20
Misc. soot	<1	
Glassy fly ash	24	1-66
Incinerator fly ash	4	0-30
Burned wood	<1	
Burned paper	<1	
Magnetite	<1	
Carbon black		
Other		
Biological Material	(1)	<1-5
Pollen	<1	
Spores	<1	
Paper	<1	
Starch	<1	0-1
Misc. plant tissue	1	0-5
Leaf trichomes		
Miscellaneous	(4)	<1-20
Iron or steel	<1	
Rubber	4	0-20
Other		